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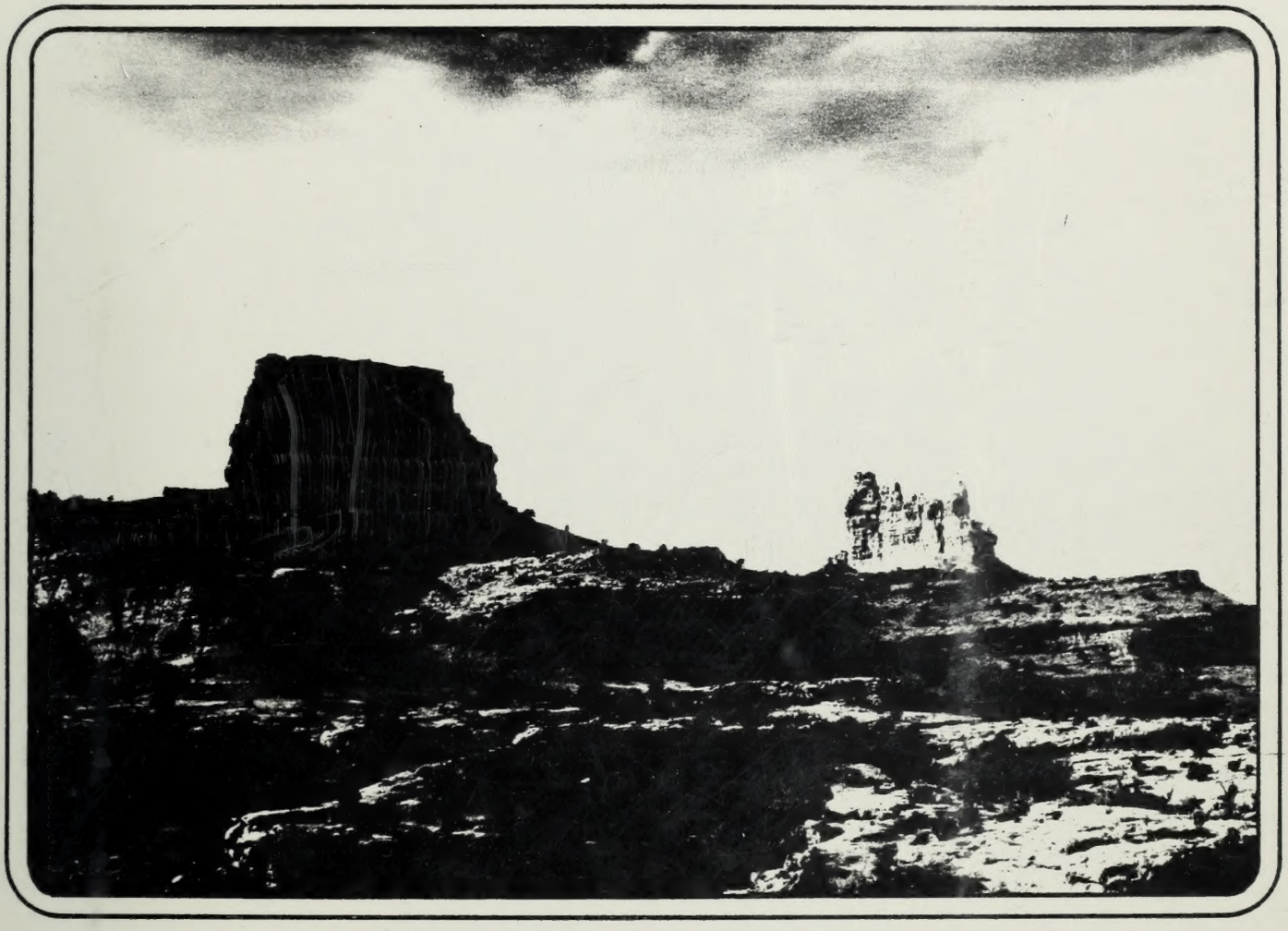

1981
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PROGRESS REPORT

ENVIRONMENTAL PROGRAMS

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WHITE RIVER SHALE PROJECT

FEDERAL PROTOTYPE OIL SHALE TRACTS Ua and Ub

prepared by

White River Shale Oil Corporation
115 South Main Street, Suite 500
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October, 1982

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SUMMARY

1.0 SUMMARY

This "Progress Report--Environmental Programs" describes field environmental monitoring studies conducted during 1981 on Federal Prototype Oil Shale Tracts Ua and Ub, collectively known as the White River Shale Project (WRSP). The two tracts totaling 10,240 acres are located in northeastern Utah, approximately 50 miles southeast of Vernal, Utah. With the exception of the water resources monitoring program, this report covers calendar year 1981. The water section is based upon the 1981 water year (October 1, 1980 through September 30, 1981).

Monitoring of environmental conditions on and near to the tracts has been an on-going responsibility of WRSP since 1974. Following completion of the lease-mandated Baseline monitoring studies (1974-1976), WRSP has conducted Interim monitoring (1977-present) of four principle environmental catagories: air resources; water resources; terrestrial wildlife resources; and vegetation resources. While continuing with these four major areas, the 1981 monitoring program was expanded to include aquatic biology and additional parameters in the terrestrial biology programs.

The principle goals of the 1981 program were threefold: first, to fully characterize the baseline environmental conditions on-tract; second, to contribute to the threatened and endangered species studies in the White River being conducted by the U. S. Fish and Wildlife Service; and third, to develop an on-going monitoring philosophy based upon our understanding of the tract ecosystem and to prepare an environmental monitoring manual to guide our continuing monitoring program. As

in previous years, the 1981 program was conducted by various environmental consultants under contract to the WRSP.

Precipitation in 1981 was well below average at the WRSP precipitation monitoring stations. To provide better coverage of the tracts, the precipitation network was increased from 8 to 10 gauges. Average precipitation for the water year was 8.03 inches (19.4 cm) varying from a high of 9.27 inches (22.3 cm) south of the tracts to a low of 6.32 inches (15.2 cm) west of the tracts. Net evaporation for the period May 1981 through September 1981 was 28.06 inches (67.6 cm) with May being the lowest month and June the highest. However, due to a change in microsite conditions near the EVP-2 pan, the true net evaporation was probably a minimum of 33.0 inches (79.5 cm). Streamflow in the White River for 1981 was considerably less than the historic average. For the period of record (1924 through 1981), only the 1934 and 1977 water years had an annual mean discharge less than 1981. The daily discharge of the White River at USGS surface water station 6395 (stateline) varied from 142 cubic feet per second (cfs) in August to 1740 cfs in June 1981. The total annual runoff for 1981 water year was 337,200 acre feet at station 6395 and 319,600 at station 6700 (below Asphalt Wash).

In general, the 1981 water quality records showed no measureable differences between stations 6395 and 6700 or between the levels observed in earlier years. The exceptions were suspended sediment levels at station 6395, which were lower due to the reduced runoff, and trace metals in one sample due to an upstream runoff source.

Although seven years of record (1975-1981) is short for establishing baseline conditions in Evacuation Creek, the 1981 annual runoff was

slightly less than the established average. The stream was influenced more by thunderstorm activity than snowmelt. Water quality was generally within the range measured previously.

An additional dry wash monitoring station was established below the proposed plant site (station 6602). No flow events were measured at either this new site or the Southam Canyon station (6610). The Asphalt Wash station 6625 measured two flow events. No water quality analyses were conducted for the dry wash stations.

The 12 bedrock aquifer monitoring wells used this year were continued from previous years. While most of the bedrock wells showed no significant change in water levels from previous years, P-2 Lower and several nearby wells showed decreasing static water levels. These changes are unexplained and will be carefully watched during 1982 and later years.

Alluvial well monitoring continued at 3 sites on-tract during 1981. Water levels and water quality showed little change between 1981 and previous years.

The air resources monitoring program continued during 1981 with one air quality monitoring site and four macro-meteorological monitoring sites. Sound level measurements were also made at five locations near the tracts beginning in October. No other significant changes were made to the air resource program.

Air quality continued to be very good over the tracts during 1981. Except for ozone, which has a non-zero background, almost all gaseous pollutant monitoring instruments measured at or near their lower threshold limits. Ozone concentrations peaked at 148 $\mu g/m^3$ in the summer,

compared with the annual standard of 235 $\mu g/m^3$. Particulate concentrations (based upon annual geometric mean) were 19.1 $\mu g/m^3$ compared with the secondary standard of 60 $\mu g/m^3$. The peak 24-hour particulate concentration was 80.4 $\mu g/m^3$ compared with the secondary standard of 150 $\mu g/m^3$.

Sound level measurements taken during 1981 confirmed the values collected during the Baseline program; 1981, 20-30dB(A), and Baseline, 24-26dB(A).

Biological resource monitoring during 1981 continued with evaluation of terrestrial vertebrate populations, vegetation resources, and reclamation research. Several additional areas of monitoring, which had been discontinued since the Baseline program, were resumed during 1981. This included soil and foliage invertebrates, aquatic biology in the White River and Evacuation Creek, and an expanded vegetation resource program including soil microbial populations, litterfall, crytogam and lichen studies, and plant condition, stress, and use.

Of the seven years of monitoring conducted by WRSP, 1981 was one of the driest, particularly for the fall-winter period which averaged 2.98 inches from October through March at the ten WRSP precipitation stations. This low moisture level affected both the annual vegetation and sagebrush leader growth. This points up the critical influence which precipitation has in determining vegetation growth and response.

Annual plant biomass was generally lower in 1981 than in other years of record; however, since annual production appears to be correlated to spring precipitation (which was about normal for 1981), the difference between 1981 and most previous years was not large. Dominant annual

species were cheatgrass, pepperwood, and lambs quarters. Production for annuals averaged 19.3 gm/m^2 with an average cover of 6.5%.

Sagebrush stem growth was very low in comparison to the seven years of record and was nearly equivalent to figures for the drought year of 1977. This correlates well with fall-winter precipitation which was low for 1981. Comparison studies between sagebrush and other shrub species showed that sagebrush stem measurements are representative of shrub growth on tract.

In other vegetation studies, the baseline elemental content of sagebrush was measured for future reference. Litterfall measurements of seven perennial species were begun in the fall to evaluate plant inputs to the nutrient system. A baseline study was begun in 1981 to determine levels of algae, lichens, and fungi on and in the soil. This data will provide a basis for assessing the impacts of development. While the tract average cryptogam cover was 8.0% with sagebrush/greasewood vegetation type highest and shadscale the lowest, there was tremendous variability with vegetation types.

Extensive soil analyses were also performed to correlate soil microbial levels to several environmental factors. The results indicated that soil bacterial and soil fungi flutuate markedly during the year, peaking in the spring and reaching minimum levels in the summer, in response to changes in soil moisture, soil temperature, and soil organic matter. The largest predictable variations in microbiological characteristics of tract soils appear to be seasonal with smaller differences occurring between vegetation types.

Several new studies were initiated in reclamation research during 1981 in addition to monitoring on-going research experiments. The new studies included interseeding and interplanting to enhance existing habitat, salt migration and root growth in processed shale, and topsoil stockpile characterization.

The existing plots on disturbed sites and in processed shale in the tract area and at Anvil Points continue to show encouraging results. In many plots stable plant communities with high survival rates have been established. In root growth experiments, excavations showed that the roots and rhizomes of plants grown in processed shale are quite healthy and show no adverse morphological changes. The newly established studies will be evaluated in succeeding years.

The soil invertebrate fauna sampled under sagebrush during 1981 comprise 30 species of nematodes, 50 species of mites and 28 species of insects with very few species of other taxa. Nematode species richness declined between April and June and increased again in October and December. Nematode density was similarly low in June and August. The same pattern was found for arthropods. These results suggest that many soil invertebrates become inactive or migrate deeper in the soil during the hot, dry, summer months, apparently in response to soil moisture and temperature. Differences in density and richness among locations were generally minimal.

Abundance, biomass, family-level diversity and richness of the invertebrate fauna are significantly different between sample periods, vegetation-types, hostplants and invertebrate feeding-types. Each terrestrial invertebrate family and feeding-type responded differently to

the phenology of the hostplant. Phytophagic suckers are the dominant feeding-type in terms of abundance and phytophagic chewers are dominant in terms of biomass in all sample periods regardless of their taxonomic composition.

Forty-three species from six orders make up the mammal community on the study site. Rodent populations were high in 1975 and 1976, low from 1977 to 1979, and high again in 1980 and 1981. Populations of cricetid rodents are highly correlated with vegetative productivity but with a one-year lag ($r=0.96$). Changes in diurnal mammal population (fairly high from 1975 to 1978, low thereafter) are due primarily to changes in desert cottontail abundance. Bat abundance was slightly lower in 1977 than in subsequent years, a possible effect of the drought. Rodents are most abundant in shrub communities (Greasewood and Shadscale) and diurnal mammals are most common in the communities with greatest ground cover (Greasewood and Riparian).

Bird communities in four habitats have been sampled five times per year from 1975 to 1981. Bird community density, consuming biomass, species richness and diversity are significantly different among years, months and habitats. Changes in avian consuming biomass over years are correlated with spring precipitation but not with annual precipitation, plant biomass or sagebrush growth. Differences among habitats are related to vegetation structure and annual-plant biomass. Concurrent with changes in the community characteristics over years are changes in the relative proportions of the trophic groups and guilds making up the community and changes in species abundance within guilds. In general,

granivores and omnivores are highly correlated with spring precipitation while insectivores are not.

Five species of amphibian and 11 species of reptile have been recorded on the study site from 1975 to 1981. Reptiles included six lizard and five snake species. Reptiles exhibited significant fluctuations in density between years and have been markedly affected by drought conditions (1977) and a severe winter (1978). Amphibians, on the other hand, were most abundant in 1975 and 1976 and have since become less common. Most amphibians are encountered in Riparian habitat and isolated ponds whereas most reptiles are encountered in the driest habitats with least ground cover, Juniper and Shadscale.

Techniques and regimes of transect observation and nocturnal mammal trapping were analyzed during 1981 to see if similar results could be obtained with less time and expense. Important characteristics of vertebrate communities estimated from three or four replications of transects were similar to those obtained from five replications. However, rare species have less chance of being detected during reduced sampling sessions. At least five replications are needed to make density estimates of bird species, but abundance estimates correlated closely to density. Most characteristics of the small mammal community could not be accurately estimated with either reduced regimes involving few traps or fewer nights of trapping. The nocturnal mammal community trapped in October 1981 was different from that in August and it was suggested that trapping in August be retained for monitoring because August trapping was used from 1975 to 1980 and several species generally declined in activity between August and October.

Aquatic biology monitoring conducted during the Baseline program had been suspended during the Interim monitoring period (1977-1980). With the onset of project construction planned for 1982 and with the probable construction of the White River Dam, it was prudent to reestablish an aquatic biology monitoring program in the White River and Evacuation Creek.

The objectives of the 1981 aquatics program were five-fold:

1. To characterize the White River and Evacuation Creek habitats in order to develop the most appropriate sampling sites for long-term monitoring.
2. Gather ecosystem-level data which would be important in tracing the fate and consequences of introduced foreign substances.
3. To develop appropriate techniques which can be utilized efficiently in a long-term monitoring program.
4. Determine those ecosystem parameters which have the greatest importance for long-term monitoring and the assessment of impacts.
5. Develop statistically significant interelationships between aquatic and other ecosystems.

While a major portion of the aquatics program was centered upon the stream systems immediately above, adjacent to, and below the tracts, a second element of the program was to conduct a detailed study of the White River ecosystem in conjunction with the U.S. Fish and Wildlife Service. These investigations have greatly expanded the information available on the physical, chemical, and biological characteristics of the White River ecosystem. Section 4.5 of this progress report describes

in detail the White River continuum, spatial and temporal dynamics within the White River, and a special study concerning Colorado Squawfish spawning sites in the Yampa River.

The 1981 WRSP monitoring program will be continued into 1982. It has provided data which completes the baseline characterization of the tract environment in advance of tract development activities. During 1982 WRSP will prepare a detailed Environmental Monitoring Manual which will carry the monitoring program into the development phase of the project. The manual will describe a sound and well-reasoned program of environmental monitoring from which the impacts of tract development can be quantified and the success of our mitigation and reclamation programs can be determined.

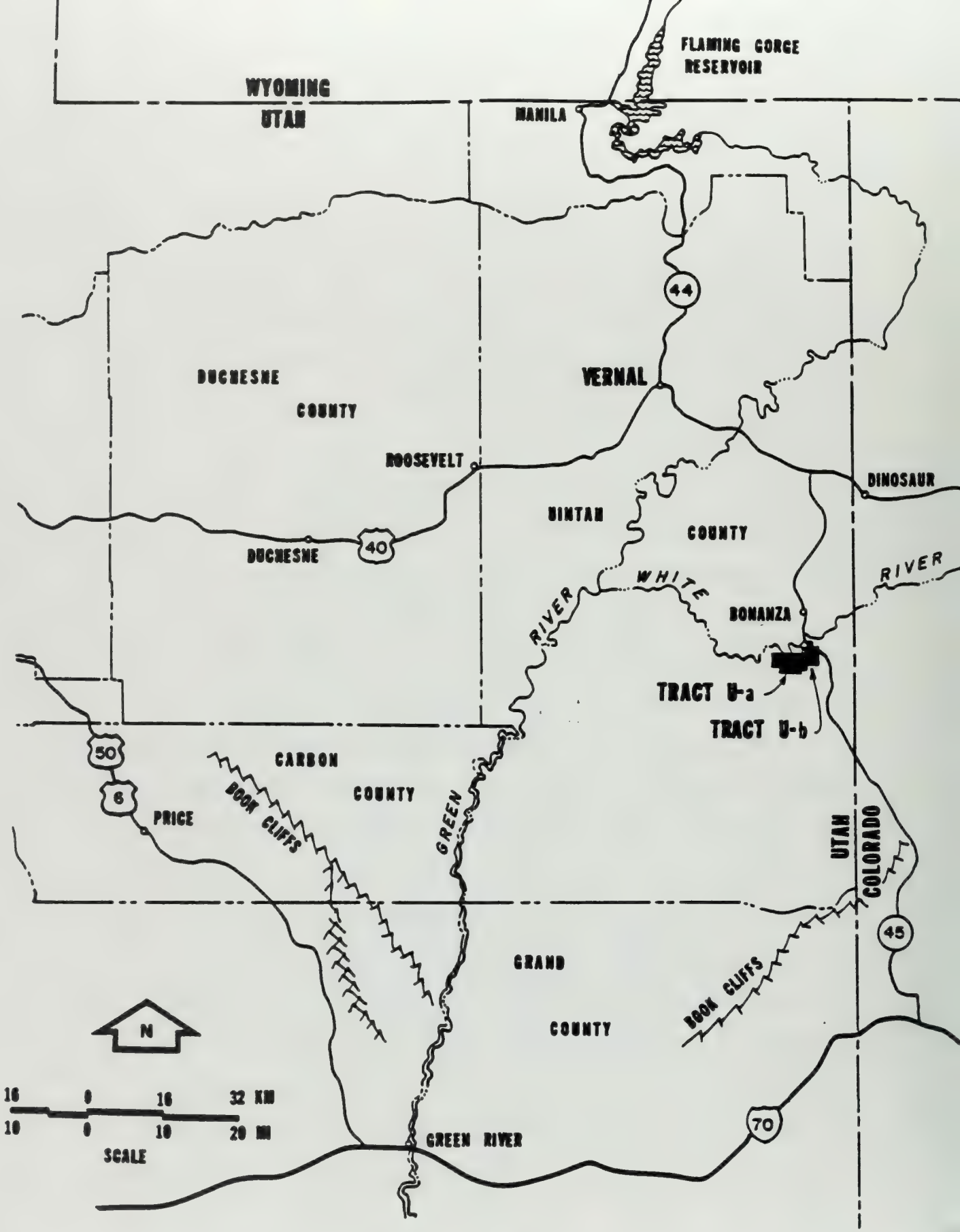
INTRODUCTION

2.0 INTRODUCTION

The White River Shale Oil Corporation, in its agency relationship to Phillips Petroleum Company, Sohio Shale Oil Company, and Sunoco Energy Development Co. (SUNEDCO), is responsible for the management and development of the oil shale resources of Federal Prototype Oil Shale Tracts Ua and Ub. This development is commonly referred to as the White River Shale Project.

The White River Shale Project (WRSP) was formed in 1974 to plan for and implement the joint development of Tracts Ua and Ub in northeastern Utah. Figure 2.0-1 shows the location of the lease tracts. Each tract encompasses 5120 acres. The lease to Tract Ua is held equally by Phillips and Sunedco and the lease to Tract Ub is held entirely by Sohio.

Three significant environmentally oriented tasks have been completed by WRSP since work under the leases began in 1974. First, the Detailed Development Plan (DDP) required by the leases was submitted to the U. S. Geological Survey -- Area Oil Shale Supervisor (AOSS) in June of 1976. This plan describes the schedule, activities, and expected results associated with the planning, construction, and operation of a commercial shale oil production facility on Tracts Ua and Ub. The DDP was revised, updated, and submitted to the Deputy Minerals Manager - Oil Shale in September 1981 for final review and approval. Approval is expected in early 1982. Second, the required two year environmental monitoring and data collection program was completed in January 1977. The results of



PROJECT LOCATION MAP

TRACTS U-a & U-b

FIGURE 2

this significant effort was published in October as the Final Environmental Baseline Report. Annual Progress Reports, such as this document, have been prepared in the interim to update environmental conditions on the lease tracts. Third, to develop a technology for revegetating disturbed sites and processed shale disposal areas, a study was conducted covering the period November 1974 through December 1978. The final report, Revegetation Studies for Disturbed Areas and Processed Shale Disposal Sites, was published in June 1979. The annual progress reports have also provided updated information on the results of WRSP's continuing reclamation research effort both on-tract and at Anvil Points, Colorado.

Development-related operations under the leases to Tracts Ua and Ub were suspended by the Department of Interior for one year starting November 1, 1976. This action postponed the approval (by the Area Oil Shale Supervisor and subsequently by the Deputy Minerals Manager - Oil Shale) and implementation of the program described in the Detailed Development Plan. These lease terms were suspended because environmental monitoring work had shown the presence of ozone and non-methane hydrocarbon gases in the air around the tracts at levels which exceeded the National Ambient Air Quality Standards. In January 1979 the standard for ozone was revised which allowed higher ambient levels of ozone. Since this change, violations of the ozone standard have not occurred on Tracts Ua/Ub.

A second suspension of lease terms became effective May 31, 1977 and preceded expiration of the first suspension period. An injunction indefinitely suspending the terms and obligations of the two leases was

granted by the Utah Federal District Court at the request of WRSP owners. The basis for this injunction involved several questions regarding the current and eventual validity of the Federal leases held by the WRSP companies. These questions arose from a dispute between the State of Utah and the Department of Interior relative to in-lieu land selection by the State, the existence of certain unpatented mining claims, and litigation concerning another company's filing for a Utah state lease on the area covered by the Federal leases to Ua and Ub. More recently an issue relative to a Ute Indian claim concerning the old Uncompaghre Reservation continued to cloud title for the tracts during 1981.

The court order suspending the terms, obligations, and conditions of Ua and Ub Federal lease terms continued in effect during 1981 although significant progress was made toward resolving the title issues.

During the interim period (1977-1981) WRSP has continued to collect data concerning air, water, and biological resources around Tracts Ua/Ub. The basic reasons for this continuing program were a desire to confirm some observations made during the baseline study period, evaluate environmental trends apparent only through multi-year study, track ambient ozone levels over an extended period, evaluate more refined biological resources monitoring techniques, and to continue the revegetation research program. The scope of activities carried out during 1981 were expanded over previous years in anticipation of resumption of tract development activities during 1982.

The purpose of this "Annual Report -- Environmental Programs" is to report on the results of activities related to WRSP's environmental monitoring, data collection, and research efforts associated with Tracts Ua and Ub during 1981.

BASELINE ENVIRONMENTAL MONITORING PROGRAM

3.0 BASELINE ENVIRONMENTAL MONITORING PROGRAM

The purpose of the Final Environmental Baseline Report was to present the results of two years of environmental baseline monitoring and data collection as required by the lease terms of the Federal Prototype Oil Shale Leases Ua and Ub. Data collection was completed on January 15, 1977, and the final report published in October 1977.

The program's purpose was to compile data to determine the environmental conditions existing on the tracts prior to any development operations under the leases. It provides a reference point for evaluating both natural and anthropogenic changes.

The baseline period was generally the years 1975 and 1976. The two baseline "water" years, however, were October 1, 1974 through September 30, 1976.

ENVIRONMENTAL MONITORING PROGRAM

4.0 ENVIRONMENTAL MONITORING PROGRAM

The purpose of this section is to discuss the work carried out during 1981 regarding the water, air, and biological resources of Tracts Ua and Ub. This work is a continuation of the WRSP environmental monitoring program that has operated without interruption since 1974.

The majority of the background environmental monitoring data necessary to satisfy the requirements of the lease, acquire permits, and provide a base for evaluating the effects of oil shale development was completed during the two-year Environmental Baseline Monitoring and Data Collection Program. Consequently, the environmental monitoring program since January 1977 has been continued for three primary reasons: (1) to maintain the applicability of the baseline results to future periods of time; (2) to track ambient ozone concentration levels, and (3) to evaluate techniques for separating natural fluctuations in the parameters that affect the ecosystem from those induced by human activities. During 1981 the monitoring program was expanded to include additional parameters in the terrestrial wildlife, vegetation, and aquatic biology resource areas. These additional study areas will reconfirm the data/results collected in the Baseline program.

The program carried out since the completion of the Baseline study is called the Interim Monitoring Program. This interim program will continue until such time as development of the oil shale resources on Tracts Ua and Ub commences. This development monitoring program, as

described in a detailed Environmental Monitoring Manual, is anticipated to begin during 1982.

The remainder of this section discusses work conducted during the period October 1, 1980 - September 30, 1981 for water resources, and during January 1, 1981 - December 31, 1981 for air and biological resources.

WATER RESOURCES

4.1 WATER RESOURCES

The two year water resources Environmental Baseline Monitoring Program was completed in total in January 1977. An Interim Monitoring Program was implemented after completion of the Baseline Program. This section of the Progress Report presents and discusses the water resources monitoring work performed during the period October 1, 1980 through September 30, 1981.

The United States Geological Survey (USGS) has been conducting a water resources data collection program in the Southeastern Uinta Basin. During the 1981 water year, the USGS efforts involved the collection of streamflow and water quality data in the immediate vicinity of Tracts Ua/Ub. The WRSP surface water monitoring program was designed to be used in conjunction with portions of the USGS program. The two data collection programs monitored streamflow, suspended sediment, and water quality on the White River, Evacuation Creek, at the mouth of Southam Canyon, and near the mouth of the Plant site wash. Also, streamflow was monitored near the mouth of Asphalt Wash.

Water level fluctuations of the Bird's Nest and Upper aquifers were continuously monitored. Additional measurements of ground water levels were recorded so that the regional ground water environment could be analyzed . Alluvial aquifers were monitored for water levels and water quality at locations downstream of the tracts on the White River, and at the mouth of Southam Canyon.

Precipitation and evaporation were monitored at the proposed plant site, in Southam Canyon, and in the surrounding area.

Data used in this report are provided in the figures and tables of the text and in the Field Data Report. All USGS data in this report are preliminary and subject to revision.

VTN Consolidated, Inc. is under contract to WRSOC to conduct the water resources monitoring program.

4.1.1 Surface Water

The surface water monitoring program is composed of work by both the USGS Water Resources Division and WRSOC. The surface water monitoring stations are listed in Table 4.1-1 and shown in Figure 4.1-1.

In the past, more than one system of nomenclature has been used for surface water stations. This report will use only the USGS system of nomenclature for station numbers and names. In addition, only the last four digits of the USGS station numbers will be used. The division of responsibility between the USGS and WRSOC is shown in Table 4.1-2.

4.1.1.1 Objective

The objectives of the surface water monitoring program are to provide continuity of record to ensure the applicability of the two-year Baseline data, and to support current and future water resources studies for this project.

TABLE 4.1-1

COMPARISON OF NOMENCLATURE FOR
SURFACE WATER STATIONS

WRSP Identification Number	USGS Identification Number	Name (USGS)
	09306395	White River near Colorado-Utah State Line, Utah
S-2	09306430	Evacuation Creek near Watson, Utah
S-16	09306602	Plant Site Wash
S-9	09306605	Southam Canyon Wash near Watson, Utah
S-13	09306610	Southam Canyon Wash at Mouth, near Watson, Utah
S-12	09306625	Asphalt Wash near mouth, near Watson, Utah
S-11	09306700	White River below Asphalt Wash, near Watson, Utah

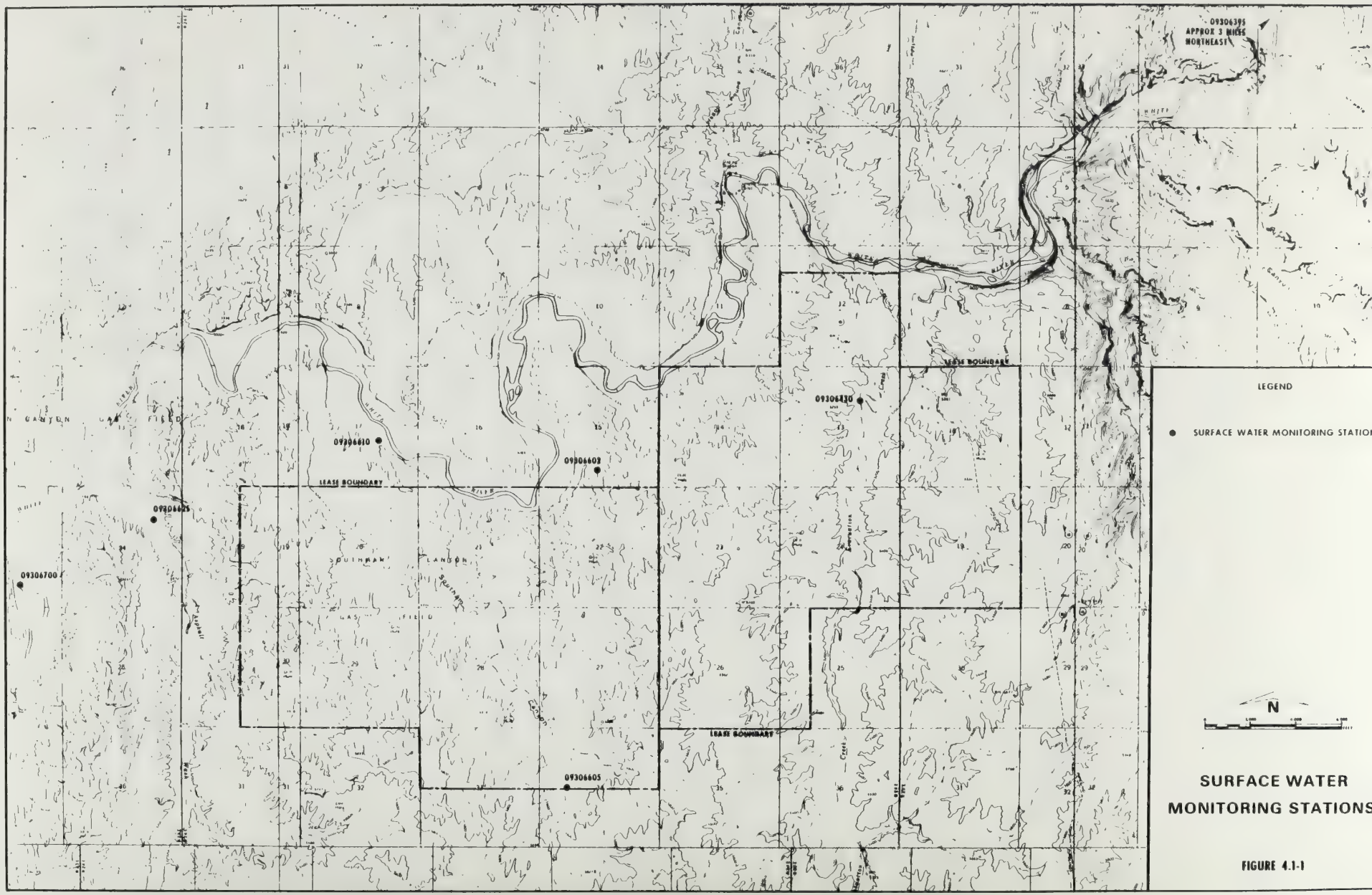

09306395
APPROX 3 MILES
NORTHEAST
LEASE BOUNDARY
09306610
09306603
09306625
09306700
09306605
LEGEND
SURFACE WATER MONITORING STATION
N
SURFACE WATER
MONITORING STATIONS

FIGURE 4.1-1

TABLE 4.1-2

RESPONSIBILITY FOR SURFACE WATER MONITORING

Station	Monitoring Activity	Responsibility
	Streamflow	
6430, 6700	Continuous monitoring	WRSOC
6602, 6610	Continuous monitoring during snowmelt and thunderstorm seasons (approximately February through October)	WRSOC
6395	Continuous monitoring	USGS
	Suspended Sediment	
6430, 6700	Periodic and opportunistic samples	WRSOC
6602, 6610	Opportunistic samples	WRSOC
6395	Continuous monitoring	USGS
	Water Quality	
6700	Continuous monitoring of temperature and specific conductance	WRSOC
6430	Quarterly samples in January, April, July and September; continuous monitoring of temperature and specific conductance	WRSOC
6602, 6610	Opportunistic samples; continuous monitoring of temperature and specific conductance during snowmelt and thunderstorm seasons	WRSOC
6395	Quarterly samples in January, April, June, and September; continuous monitoring of temperature and specific conductance	USGS

4.1.1.2 Program Design and Methodology

Data collection efforts during the 1981 water year were concerned with streamflow, suspended sediment, and water quality.

Streamflow

Streamflow was monitored continuously by WRSOC on the White River downstream from tracts (station 6700) and on Evacuation Creek near its confluence with the White River (station 6430). In addition, streamflow was monitored continuously by WRSOC at the mouth of Southam Canyon (station 6610), an ephemeral drainage, during the snowmelt and thunder storm seasons. This station was in operation from October 1 to November 4 and from March 16 to September 30.

A new surface water monitoring station (6602, located near the mouth of an ephemeral drainage in which the proposed plant site is located) was established by WRSOC in coordination with the OSO. This new station was in operation from June 16 to September 30.

Streamflow was also monitored continuously by the USGS at station 6395 on the White River upstream of the tracts and at Station 6625 near the mouth of Asphalt Wash.

Suspended Sediment

Suspended sediment was monitored by WRSOC at stations 6700, 6430, 6610 and 6602. All samples from these stations were analyzed by WRSOC. The USGS monitored suspended sediment at station 6395. These

samples were analyzed by the USGS District Laboratory in Salt Lake City, Utah.

Water Quality

Water quality samples were collected by WRSOC at station 6430 in January, April, July and September. The USGS collected a supplemental water quality sample in August. No samples were collected at stations 6610 and 6602 because there were no flow events during the year. In April and September, WRSOC collected supplemental samples at station 6700 to assist the aquatics program and analyzed them for selected trace materials. The USGS also collected water quality samples at station 6395 in October, November, February, March, April, June, July, August and September. All water quality samples collected by WRSOC and the USGS were analyzed at the USGS Central Laboratory in Denver, Colorado.

Temperature and specific conductance were monitored continuously by WRSOC at stations 6700 and 6430. Station 6610 was monitored continuously from October 1 through November 4 and from March 16 through September 30. The USGS monitored temperature and specific conductance continuously at station 6395.

The methods used to collect data at surface water monitoring stations followed procedures established during previous years and discussed in earlier reports. However, WRSOC did upgrade equipment at certain monitoring stations.

Quality Assurance/Quality Control Plan

As part of the WRSP Environmental Program, a QA program was developed to ensure the quality of the water resource data produced throughout this monitoring effort. The QA program includes formulation of a QA program plan, implementation of a Data Management System, and integration of a series of field and office procedures designed to ensure the accuracy, precision, completeness, representativeness and comparability of data. The QA program also includes the implementation of technical reviews and audits that document the success of the QA/QC effort.

Data Management System

The Data Management System implemented for the Water Resources Program involved designing a computerized water quality storage and retrieval system that is similar in structure to, and fully compatible with, the USGS Water Storage and Retrieval System (WATSTORE). This sequential-indexed file provides a means of managing instantaneous data (associated with a specified date and time) that are collected in both the field and laboratory. A second component of the Data Management System is the daily values file for continuously recorded data. Both of these data storage systems were implemented in 1981.

4.1.1.3 Data Summary

Steamflow

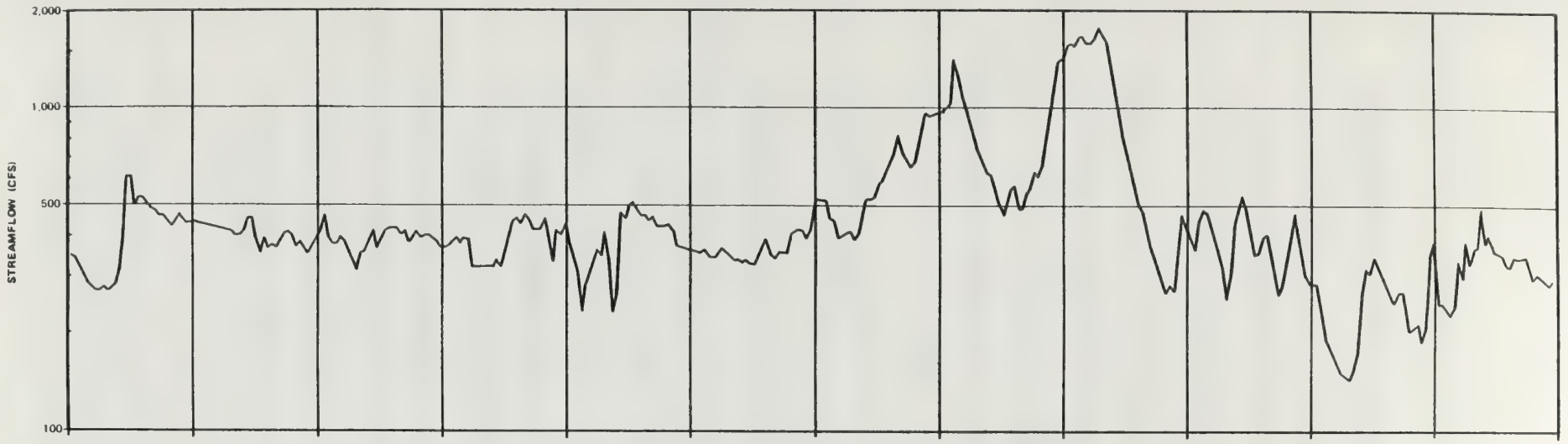
White River. Baseflow in the White River occurred from October through mid-February, and resumed in late June. Runoff from snowmelt

in the lower basin generally occurred from mid-February through late April. Runoff from snowmelt in the upper basin began in mid-April and lasted through most of June. The 1981 streamflow hydrographs for stations 6395 and 6700 on the White River are shown in Figure 4.1-2.

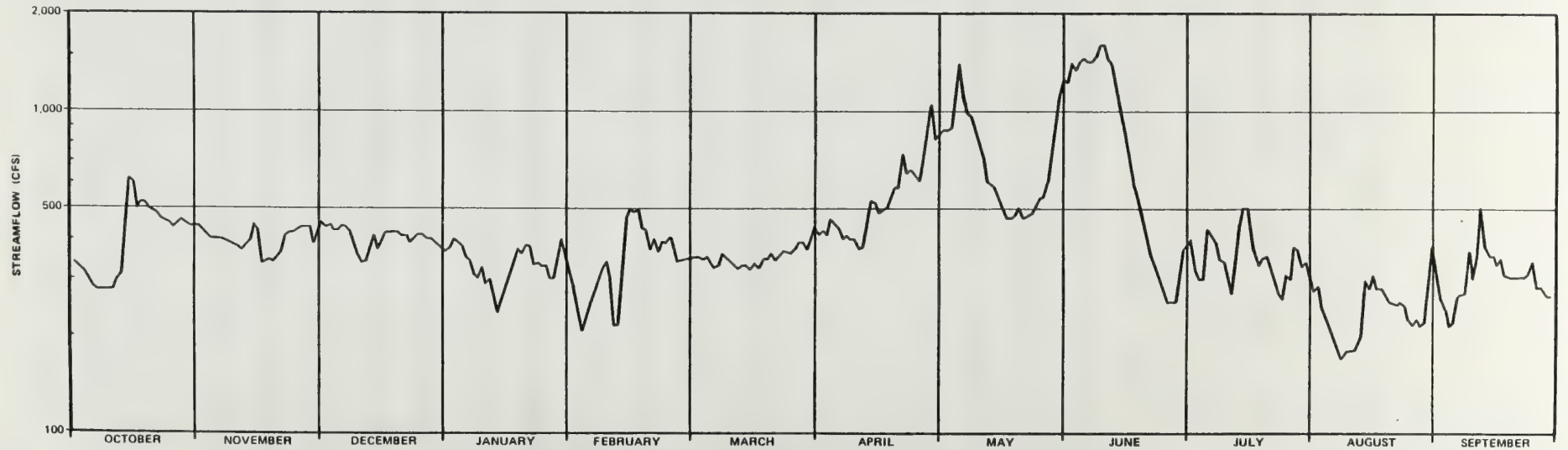
The highest value of mean daily streamflow for stations 6395 and 6700 was 1,740 cfs at station 6395 on June 9. This station also sustained the maximum instantaneous streamflow during the year of 1,920 cfs on June 9. The lowest value of mean daily streamflow was 142 cfs, also occurred at station 6395 on August 10. The total annual runoff at station 6395 was 337,200 acre-feet, and was 319,600 acre-feet at station 6700. This difference amounts to a decrease in total annual runoff of 5.2% from the upstream station to the downstream station.

Evacuation Creek. Snowmelt runoff began in Evaucation Creek during the month of March and lasted until mid-June. During most of the year, the streamflow of Evacuation Creek was sustained by baseflow, however, runoff from thunderstorms produced several short-duration rises in streamflow. Mean daily streamflow at this station ranged from a minimum of 0.10 cfs on several days to a maximum of 52 cfs on September 24. The maximum instantaneous streamflow during the year was 380 cfs on July 24. Total annual runoff was 906 acre-feet. The 1981 streamflow hydrograph for station 6430 near the mouth of Evacuation Creek is shown in Figure 4.1-3.

Dry Washes. No flow occurred during the year at station 6602 in the plant site drainage, nor at station 6610 at the mouth of Southam

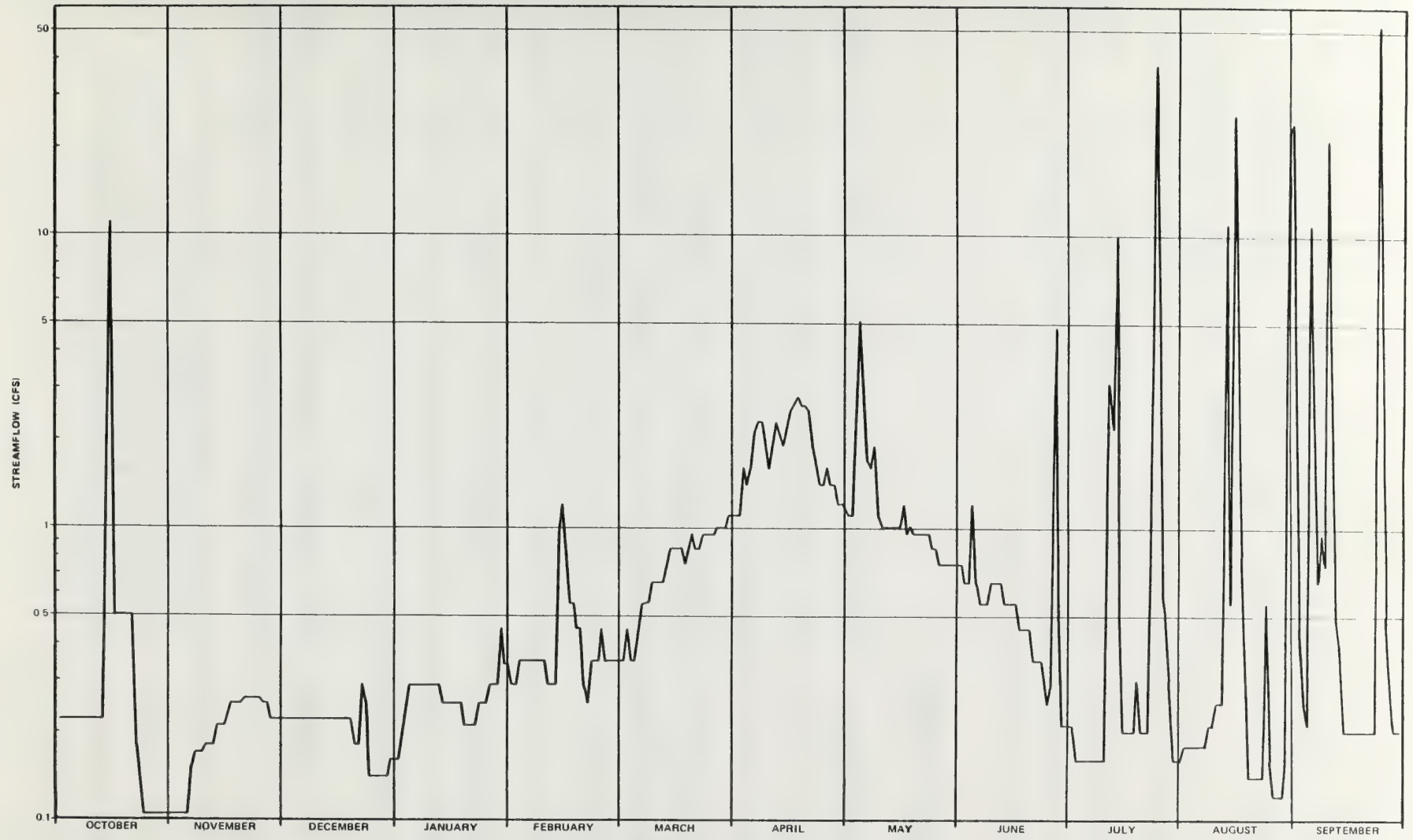


WHITE RIVER NEAR COLORADO STATE LINE, UTAH (Sta. 09306395)
MEAN DAILY STREAMFLOW
OCTOBER 1980 – SEPTEMBER 1981



WHITE RIVER BELOW ASPHALT WASH, NEAR WATSON, UTAH (Sta. 09306700)
MEAN DAILY STREAMFLOW
OCTOBER 1980 – SEPTEMBER 1981

FIGURE 4.1-2



EVACUATION CREEK NEAR MOUTH, NEAR WATSON, UTAH (Sta. 09306430)

MEAN DAILY STREAMFLOW

OCTOBER 1980 – SEPTEMBER 1981

FIGURE 4.1 3

Canyon. Station 6625 near the mouth of Asphalt Wash recorded a flow on two days during the year. The mean daily streamflow on July 2 was 0.11 cfs, and 14 cfs on August 30. The maximum instantaneous streamflow during the year at station 6625 was 458 cfs on August 30. The minimum daily streamflow for these three stations was zero. The 1981 total annual runoff for stations 6602 and 6610 was zero, and was 28 acre-feet for station 6625.

Suspended Sediment

White River. Instantaneous concentrations and loads of suspended sediment for White River stations 6395 and 6700 collected during the 1981 water year are summarized in Table 4.1-3 and 4.1-4. All sediment samples at 6700 were collected manually. At station 6395, the USGS sampled for sediment using a PS-69 pumping sampler. These samples are not included in this report; however, the manually collected sample data for this station are shown in Table 4.1-3. The maximum instantaneous suspended sediment concentrations (from the manually collected samples) for stations 6395 and 6700 during 1981 were 3,460 mg/l and 3,610 mg/l, respectively.

The 1981 mean daily suspended sediment concentrations and sediment loads station for 6395 are presented in Table 4.1-5. The months of May and June contribute by far the largest sediment loads coinciding with the increase in streamflow from upper basin runoff. Minimum sediment loads most commonly occurred during the stable baseflow periods of winter and summer. This fact is reinforced by the sediment

TABLE 4.1-3. WHITE RIVER NEAR COLORADO STATE LINE (09306395)
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)	SEDI-MENT, SUS-PENDED (MG/L)	SUSP SEDI-MENT DIS-CHARGE (T/DAY)
10/06/80	1500	300	13.0	800	8.1	8.6	--	--
11/21/80	1400	451	0.5	880	7.8	11.7	--	--
11/21/80	1415	451	0.5	--	--	--	214	260
02/19/81	1300	554	0.0	770	7.5	11.9	--	--
03/18/81	1200	371	8.5	950	7.4	--	--	--
03/31/81	1410	410	7.5	--	--	--	362	400
04/16/81	1530	550	16.0	760	7.7	--	--	--
04/29/81	1115	993	14.5	--	--	--	1210	3240
06/02/81	1600	1530	16.5	460	7.6	7.5	--	--
06/02/81	1630	1340	16.5	--	--	--	1340	4850
07/08/81	1200	340	23.0	760	7.9	7.1	--	--
07/14/81	1200	556	23.0	780	8.0	6.6	--	--
08/17/81	1130	326	21.0	--	--	--	3410	3050
08/25/81	1015	200	20.5	850	8.6	7.6	-	--
09/03/81	1030	227	--	--	7.7	7.1	--	--
09/03/81	1100	227	17.5	--	--	--	1810	1110
09/24/81	1330	305	12.5	710	8.1	7.6	--	--

TABLE 4.1-4. WHITE RIVER BELOW ASPHALT WASH (09306700)
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)	SEDI-MENT, SUS-PENDED (MG/L)	SUSP SEDI-MENT DIS-CHARGE (T/DAY)
10/07/80	1145	E295	15.6	830	8.6	10.0	70	55
10/14/80	1030	339	12.0	860	8.6	8.4	145	132
11/03/80	1020	E408	5.5	828	8.4	9.2	171	188
11/10/80	1000	387	5.3	814	7.8	8.2	232	242
12/01/80	1030	493	2.0	816	8.4	9.6	496	660
01/05/81	1010	338	0.6	860	8.8	8.2	209	190
02/02/81	1010	237	0.1	840	8.3	11.4	198	126
02/16/81	1000	507	0.1	840	8.2	10.4	1020	1400
03/04/81	1030	348	5.0	960	8.3	10.4	203	190
03/16/81	1130	E340	6.4	--	8.2	9.5	140	128
04/02/81	0915	443	8.8	990	8.6	9.6	541	647
04/30/81	0815	E835	15.0	436	8.0	7.8	--	--
05/04/81	1035	951	12.8	570	8.2	--	3610	9270
05/12/81	1030	588	15.0	590	8.4	8.0	684	1090
05/26/81	1045	531	17.4	700	7.8	8.0	509	729
06/04/81	0930	1398	17.0	420	8.4	7.6	2290	8640
06/08/81	1115	1489	18.5	410	8.4	--	1910	7680
06/17/81	1100	635	17.5	--	7.4	--	545	934
06/26/81	1000	275	23.6	810	8.4	7.0	145	107
07/06/81	1115	418	23.5	750	--	7.2	288	325
07/20/81	1100	387	22.0	890	8.4	7.0	732	764
08/02/81	1040	239	23.8	820	8.2	7.2	181	116
08/20/81	1100	248	20.5	940	8.6	--	459	307
09/03/81	1030	260	18.0	950	8.6	8.0	2400	1680
09/17/81	0950	327	17.8	800	8.7	7.4	796	702
09/29/81	1000	E261	14.2	820	8.4	--	--	--

NOTE: E = ESTIMATED

TABLE 4.1-5. WHITE RIVER [illegible]
SUSPENDED-SEDIMENT DISCHARGE (TONS/DAY), WATER [illegible]

DAY	MEAN DISCHARGE (CFS)	MEAN CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)	MEAN DISCHARGE (CFS)	[illegible] CONCEN-TRATION (MG/L)	[illegible]	[illegible]	[illegible]
		OCTOBER			[illegible]			
1	346	91	85	446	[illegible]			
2	339	62	57	440	[illegible]			
3	322	79	69	433	[illegible]			
4	305	66	54	431	[illegible]			
5	288	64	50	427	[illegible]			
6	260	92	70	423	[illegible]			
7	271	119	87	424	[illegible]			
8	271	130	95	419	[illegible]			
9	276	127	95	415	[illegible]			
10	269	126	92	411	[illegible]			
11	276	132	98	402	[illegible]			
12	285	145	112	402	[illegible]			
13	314	121	103	414	[illegible]			
14	388	428	448	456	[illegible]			
15	486	1040	1700	455	[illegible]			
16	605	870	1420	388	[illegible]			
17	499	636	857	351	[illegible]			
18	502	544	767	390	[illegible]			
19	522	522	736	364	[illegible]			
20	498	444	597	371	[illegible]			
21	487	372	489	376	[illegible]			
22	479	342	442	390	[illegible]			
23	459	286	354	403	[illegible]			
24	457	252	311	409	[illegible]			
25	444	274	328	401	[illegible]			
26	431	272	317	370	[illegible]			
27	447	276	333	360	[illegible]			
28	461	244	304	370	[illegible]			
29	450	198	241	359	[illegible]			
30	438	304	360	370	[illegible]			
31	440	204	242	---	---			
TOTAL	12475		11313	12085				

TABLE 4.1-5 (CONTINUED). WHITE RIVER NEAR COLORADO STATE LINE (09306395)
SUSPENDED-SEDIMENT DISCHARGE (TONS/DAY), WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DAY	MEAN DISCHARGE (CFS)	MEAN CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)	MEAN DISCHARGE (CFS)	MEAN CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)	MEAN DISCHARGE (CFS)	MEAN CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)
		JANUARY			FEBRUARY			MARCH	
1	365	120	118	373	390	393	355	326	312
2	370	128	128	350	400	378	352	302	287
3	385	129	134	305	419	345	352	285	271
4	393	102	108	232	386	242	354	285	272
5	381	107	110	280	410	310	341	270	249
6	395	109	116	317	418	358	339	250	229
7	388	104	109	334	415	374	348	239	225
8	320	105	91	360	410	399	366	243	240
9	320	113	98	342	425	392	350	229	216
10	320	121	105	411	470	522	345	222	207
11	320	125	108	329	443	394	333	215	193
12	320	145	125	230	435	270	333	209	188
13	318	172	148	257	447	310	330	205	183
14	333	195	175	472	480	612	336	205	186
15	323	195	170	451	491	598	325	207	182
16	343	235	218	488	479	631	324	205	179
17	391	299	316	502	475	644	333	205	184
18	442	320	382	485	468	613	357	191	184
19	452	339	414	462	480	599	291	335	354
20	436	338	398	457	475	586	350	250	236
21	461	373	464	441	468	557	340	293	269
22	445	375	451	456	463	570	350	252	238
23	411	405	449	425	455	522	350	200	189
24	411	415	461	423	462	528	350	258	244
25	414	409	457	426	402	462	398	470	505
26	444	392	470	429	391	453	412	384	427
27	388	392	411	410	380	421	417	573	645
28	332	393	352	371	352	353	414	464	519
29	413	422	471	---	---	---	388	393	412
30	403	410	446	---	---	---	414	449	502
31	481	498	475	---	---	---	499	478	554
TOTAL	11869		8479	10818		12806	11235		9193

TABLE 4.1-5 (CONTINUED). WHITE [illegible]
SUSPENDED-SEDIMENT DISCHARGE (TONS/DAY), WATER [illegible]

DAY	MEAN DISCHARGE (CFS)	MEAN CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)	MEAN DISCHARGE (CFS)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		APRIL							
1	516	343	478	972	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	512	377	521	993	[illegible]	[illegible]	[illegible]	[illegible]	
3	515	594	826	1010	[illegible]	[illegible]	[illegible]	[illegible]	
4	448	445	538	1390	[illegible]	[illegible]			
5	444	421	505	1260	[illegible]	[illegible]			
6	393	502	533	1040	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	397	410	439	995	[illegible]	[illegible]	[illegible]		
8	406	405	444	922	[illegible]	[illegible]			[illegible]
9	410	264	292	789	[illegible]	[illegible]	[illegible]		[illegible]
10	335	221	230	734	[illegible]	[illegible]	[illegible]		
11	402	218	237	666	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	486	341	447	621	[illegible]	[illegible]	[illegible]		[illegible]
13	516	469	652	614	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	514	394	552	569	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	520	339	475	507	[illegible]	[illegible]	[illegible]		[illegible]
16	570	415	639	474	[illegible]	[illegible]	[illegible]		[illegible]
17	583	479	740	491	[illegible]	[illegible]	[illegible]		
18	626	740	1180	581	[illegible]	[illegible]	[illegible]	[illegible]	
19	663	785	1410	589	[illegible]	[illegible]	[illegible]	[illegible]	
20	714	875	1690	477	[illegible]	[illegible]	[illegible]		
21	822	1410	3130	456	[illegible]	[illegible]	[illegible]		
22	717	785	1480	549	[illegible]	[illegible]	[illegible]	[illegible]	
23	694	670	1250	583	[illegible]	[illegible]	[illegible]		
24	653	575	1061	[illegible]	[illegible]	[illegible]			
25	671	607	[illegible]	[illegible]	[illegible]	[illegible]			
26	757	740	1510	[illegible]	[illegible]	[illegible]			
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
28	951	1760	4520	[illegible]	[illegible]	[illegible]			
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
30	[illegible]	[illegible]	2480	[illegible]	[illegible]	[illegible]			
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
TOTAL	19086		[illegible]	[illegible]					

TABLE 4.1-5 (CONTINUED). WHITE RIVER NEAR COLORADO STATE LINE (09251050)
SUSPENDED-SEDIMENT DISCHARGE (TONS/DAY), WATER YEAR OCTOBER 1990 TO SEPTEMBER 1991

DAY	MEAN DISCHARGE (CFS)	MEAN CONCENTRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)	MEAN DISCHARGE (CFS)	MEAN CONCENTRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)	MEAN DISCHARGE (CFS)	MEAN CONCENTRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)
		JULY			AUGUST			SEPTEMBER	
1	365	346	360	282	285	217	244	2410	1590
2	360	440	428	263	290	206	243	1570	1030
3	443	1820	2180	222	301	180	233	1700	1070
4	481	705	916	191	288	149	224	784	474
5	469	405	513	177	285	136	240	480	311
6	423	316	361	171	244	113	334	1100	992
7	381	278	286	158	153	65	294	870	691
8	347	236	221	148	138	55	378	1280	1310
9	318	246	211	146	150	59	324	1010	884
10	252	202	137	142	120	46	361	1720	1680
11	306	292	241	153	130	54	364	1040	1020
12	435	7050	8280	173	193	90	479	5800	7500
13	481	13500	17500	263	2880	2050	377	3060	3110
14	527	2400	3410	318	4380	3760	395	2540	2720
15	477	351	452	301	1130	918	360	1690	1640
16	387	360	376	340	1500	1380	351	1080	1020
17	347	312	292	321	2450	2120	344	630	585
18	348	324	304	307	990	821	326	580	511
19	390	357	376	279	749	564	319	470	405
20	399	350	377	259	640	448	340	510	468
21	344	345	320	244	536	353	337	470	428
22	313	318	269	260	516	362	334	377	340
23	262	295	209	265	522	373	341	351	323
24	278	1120	841	243	445	292	307	244	204
25	334	4560	4470	201	366	209	291	109	84
26	368	5070	5040	204	343	189	303	102	83
27	467	4220	5310	208	350	197	291	122	96
28	374	920	929	184	400	201	287	108	84
29	339	430	395	205	579	320	278	112	84
30	297	314	252	341	4910	4520	288	132	103
31	282	329	245	360	3560	3450	---	---	---
TOTAL	11614		55512	7751		24097	9589		30844
MEAN	374.6		1791						

records for station 6395 from 1977 to 1981, as summarized in Table 4.1-6. However, occasional intense rainstorms in late summer, can cause considerable short-term sediment transport, as was recorded in 1977 and 1978. The annual sediment load transported in 1981 (398,000 tons) was substantially less than recorded in 1980 (1,500,000 tons). This was due primarily to the much greater runoff of 1980 (526,500 ac-ft) as compared to 1981 (337,200 ac-ft).

Evacuation Creek. Instantaneous suspended sediment data collected at Evacuation Creek (6430) during 1981 are shown in Table 4.1-7. The maximum instantaneous sediment concentration (93,100 mg/l) and sediment load (15,300 tons/day) were both recorded on October 15, 1980, during a heavy rainfall event. Sediment concentrations during the winter baseflow period were stable, ranging from 23 mg/l to 149 mg/l and increased slightly during the spring snowmelt period. Another high sediment concentration value (68,300 mg/l) was sampled during a summer rainstorm. Because of the extremely flashy nature of the storm-runoff in Evacuation Creek, a much greater instantaneous sediment load was transported during these intense rainfall events than during snowmelt runoff. This observation has been noted during each year of monitoring at Evacuation Creek.

Dry Washes. No sediment samples were collected at the dry washes due to a lack of streamflow (stations 6602, 6610).

TABLE 4.1-6

MAXIMUM AND MINIMUM DAILY SUSPENDED SEDIMENT LOADS
AND TOTAL ANNUAL LOADS FROM 1977 to 1981 FOR
WHITE RIVER NEAR COLORADO STATE LINE, UTAH (09306395)

	1977	1978	1979	1980	1981
Maximum Daily Sediment Load (tons/day)	36,000 (7/25)	412,000 (9/8)	60,000 (5/30)	48,600 (5/24)	23,100 (5/4)
Minimum Daily Sediment Load (tons/day)	1.0 (7/2-7/3)	24 (12/22)	34 (12/3)	128 (8/16)	50 (10/5)
Total Annual Sediment Load (tons)	367,848	1,489,067	1,235,377	1,504,368	397,862

TABLE 4.1-7. EVACUATION CREEK NEAR MOUTH (09306430)
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)	SEDI-MENT, SUS-PENDED (MG/L)	SUSP SEDI-MENT DIS-CHARGE (T/DAY)
10/15/80	1010	61	6.5	1050	8.4	9.8	93100	15500
11/05/80	1300	0.10	17.6	4100	8.2	11.5	25	0.01
11/20/80	1100	0.26	9.0	4100	8.6	11.0	79	0.06
12/02/80	1145	0.22	7.0	4210	9.8	8.6	57	0.03
12/18/80	1010	0.22	4.8	--	--	--	--	--
01/06/81	1405	0.29	10.0	4350	8.0	6.5	36	0.03
01/20/81	1005	0.23	6.5	4500	8.4	10.2	51	0.03
01/29/81	1005	0.29	6.5	4500	8.0	7.6	128	0.10
01/29/81	1210	0.29	9.5	4500	8.0	7.6	--	--
02/03/81	1200	0.30	10.5	4400	7.8	8.5	149	0.12
02/13/81	1100	E0.30	9.8	4500	8.2	10.2	16	0.01
02/23/81	1145	0.38	13.3	4500	8.0	8.2	23	0.02
03/05/81	1220	0.40	14.3	4550	8.6	11.4	38	0.04
03/17/81	1030	0.80	10.8	--	--	--	93	0.20
04/06/81	1115	2.0	15.2	4600	8.0	8.0	501	2.7
04/16/81	1010	2.6	16.5	4100	8.0	8.0	538	3.7
04/30/81	0915	E1.2	13.0	4100	7.6	8.6	--	--
05/05/81	1030	2.3	15.2	4700	8.2	7.8	565	3.5
05/27/81	0945	0.70	15.8	4100	--	9.0	212	0.40
06/03/81	1140	0.65	19.6	4700	--	--	271	0.48
07/01/81	0945	0.21	16.8	4500	8.2	--	422	0.24
07/13/81	0915	13	18.8	1400	--	7.2	62300	2400
07/29/81	0940	0.18	16.2	4550	8.4	6.4	87	0.04
07/29/81	1100	0.18	21.0	4550	8.4	6.4	--	--
08/08/81	0930	0.26	16.0	4650	8.2	10.2	1[illegible]	[illegible]
08/19/81	1115	0.15	20.0	4550	8.3	--	1[illegible]	[illegible]
08/25/81	1010	0.23	29.0	3750	8.2	6.8	--	--
09/02/81	1000	0.70	15.5	3000	8.5	6.6	1[illegible]	[illegible]
09/09/81	1015	0.87	15.1	3800	8.3	9.2	1[illegible]	[illegible]
09/30/81	0930	E0.18	14.2	4700	8.0	[illegible]		

NOTE: E = ESTIMATED

Water Quality

White River. Field samples for station 6700 were analyzed for selected trace materials, and were collected as supplemental information useful to the aquatics program on the White River. The 1981 water quality data for stations 6395 and 6700 are presented in Tables 4.1-3, 4.1-4 and 4.1-8.

The maximum recorded instantaneous temperature at station 6395 and 6700 was 27.5°C, while the minimum recorded instantaneous temperature was 0.0°C. The maximum recorded instantaneous specific conductance value at station 6395 was 950 micromhos/cm on March 18, and 1,420 micromhos/cm at station 6700 on August 14. The minimum recorded instantaneous specific conductance value at station 6395 was 320 micromhos/cm on June 6 and 9, and 398 micromhos/cm at station 6700 on June 21. The continuous records of mean daily temperature and specific conductance for stations 6395 and 6700 are shown in Figures 4.1-4 and 4.1-5.

A comparison of the continuous records of specific conductance between these two stations clearly indicated the effects of occasional large flow events from Evacuation Creek and Asphalt Wash due to summer thunderstorm runoff. Generally, these events caused a short duration rise in the conductivity of the White River at the downstream station (number 6700).

The values of pH were relatively stable during the year at both stations, and ranged from 7.4 to 8.7. Dissolved oxygen was

TABLE 4.1-8. SUMMARY OF WHITE RIVER STATIONS
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

STATION NUMBER	DATE	TIME	TOTAL DISS SOLIDS (SUM) (MG/L)	CALCIUM DISS (MG/L)	MAGNE-SIUM DISS (MG/L)	POTAS-SIUM DISS (MG/L)	SODIUM DISS (MG/L)	BICAR-BONATE (MG/L)	CHLOR-IDE DISS (MG/L)	SUL-FATE DISS (MG/L)
09306395	10/06/80	1500	525	69	28	1.9	69	207	44	200
	11/21/80	1400	523	71	28	2.3	73	256	37	170
	02/19/81	1300	457	61	23	1.6	65	195	37	160
	03/18/81	1200	577	71	30	1.7	78	232	41	230
	04/16/81	1530	449	63	24	1.7	55	195	27	170
	06/02/81	1600	241	46	14	1.6	21	134	9	70
	07/08/81	1200	476	66	27	1.8	54	195	37	180
	07/14/81	1200	475	74	26	2.4	50	232	33	160
	08/25/81	1015	521	69	29	2.2	66	207	39	200
	09/03/81	1030	620	87	32	4.1	71	232	46	250
	09/24/81	1330	--	--	--	--	--	--	--	--
09306700	04/30/81	0815	--	--	--	--	--	--	--	--
	09/29/81	1000	--	--	--	--	--	--	--	--

STATION NUMBER	DATE	TIME	FLUOR-IDE DISS (MG/L)	SILICA DISS (MG/L)	ALKALI-NITY, LAB (MG/L AS CACO3)	HARD-NESS TOTAL (AS CACO3) (MG/L)	HARD-NESS, NONCAR. (AS CACO3) (MG/L)	SODIUM ADSORP RATIO (SAR)	PERCENT SODIUM	OXYGEN DEMAND, CHEM (HIGH LEVEL) (MG/L)
09306395	10/06/80	1500	0.3	11	170	290	120	1.8	34	--
	11/21/80	1400	0.5	15	210	290	83	1.9	35	--
	02/19/81	1300	0.3	12	160	250	87	1.8	36	--
	03/18/81	1200	0.3	11	190	300	111	2.0	36	--
	04/16/81	1530	0.2	12	160	260	96	1.5	32	--
	06/02/81	1600	0.1	12	110	170	62	0.7	21	24
	07/08/81	1200	0.2	13	160	280	116	1.4	30	--
	07/14/81	1200	0.2	15	190	290	102	1.3	27	--
	08/25/81	1015	0.3	13	170	290	122	1.8	33	40
	09/03/81	1030	0.3	15	190	350	159	1.8	30	--
	09/24/81	1330	--	--	--	--	--	--	--	42
09306700	04/30/81	0815	--	--	--	--	--	--	--	48
	09/29/81	1000	--	--	--	--	--	--	--	35

TABLE 4.1-8 (CONTINUED). SUMMARY OF WHITE RIVER STATIONS
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

STATION NUMBER	DATE	TIME	ORGANIC CARBON DISS (MG/L)	OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG/L)	AMMONIA DISS (AS N) (MG/L)	NITRITE DISS (AS N) (MG/L)	NITRATE DISS (AS N) (MG/L)	NITRITE PLUS NITRATE DISS (AS N) (MG/L)	NITRO-GEN, ORGANIC DISS (AS N) (MG/L)	AMMONIA + ORG NITRO DISS (AS N) (MG/L)
09306395	10/06/80	1500	--	--	--	--	--	0.00	--	--
	11/21/80	1400	--	--	--	--	--	0.00	--	--
	02/19/81	1300	--	--	--	--	--	0.15	--	--
	03/18/81	1200	--	--	--	--	--	0.00	--	--
	04/16/81	1530	--	--	--	--	--	0.04	--	--
	06/02/81	1600	--	--	0.130	--	--	0.15	--	--
	07/08/81	1200	--	--	--	--	--	0.09	--	--
	07/14/81	1200	--	--	--	--	--	0.12	--	--
	08/25/81	1015	5.1	0	0.060	0.010	0.01	0.02	0.62	0.68
	09/03/81	1030	--	--	--	--	--	0.00	--	--
	09/24/81	1330	4.9	--	0.030	--	--	--	--	--
09306700	04/30/81	0815	8.5	--	--	--	--	--	--	--
	09/29/81	1000	3.3	--	--	--	--	--	--	--

STATION NUMBER	DATE	TIME	NITRO-GEN DISS (AS N) (MG/L)	PHOS-PHORUS DISS. (AS P) (MG/L)	PHOS-PHORUS, TOTAL (AS P) (MG/L)	PHOS-PHORUS, ORTHO DISS (AS P) (MG/L)	ALUM-INUM DISS (UG/L)	ALUM-INUM, SUS-PENDED RECOV. (UG/L)	ALUM-INUM, TOTAL (UG/L)	ARSENIC DISS (UG/L)
09306395	10/06/80	1500	--	0.010	--	0.000	0	--	--	1
	11/21/80	1400	--	0.000	--	--	--	--	--	--
	02/19/81	1300	--	0.010	--	--	--	--	--	--
	03/18/81	1200	--	0.010	--	--	--	--	--	--
	04/16/81	1530	--	0.040	--	0.010	--	--	--	--
	06/02/81	1600	--	0.020	0.270	--	20	--	--	1
	07/08/81	1200	--	--	--	0.070	--	--	--	--
	07/14/81	1200	--	0.010	--	--	--	--	--	--
	08/25/81	1015	0.70	0.020	--	0.000	10	1600	1600	2
	09/03/81	1030	--	0.020	--	--	--	--	--	--
	09/24/81	1330	--	--	0.030	--	0	--	--	--

TABLE 4.1-8 (CONTINUED). SUMMARY OF WHITE RIVER STATIONS
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

STATION NUMBER	DATE	TIME	ARSENIC SUS-PENDED TOTAL (UG/L)	ARSENIC TOTAL (UG/L)	ARSENIC TOTAL IN BOT-TOM MA-TERIAL (UG/G)	BARIUM DISS (UG/L)	BARIUM, TOTAL IN BOT-TOM MAT (UG/G)	BERYL-LIUM DIS-OLVED (UG/L)	BERYL-LIUM, TOTAL (UG/L)	BERYL-LIUM, TOTAL IN BOT-TOM MAT (UG/G)
09306395	10/06/80	1500	--	--	--	--	--	--	--	--
	11/21/80	1400	--	--	--	--	--	--	--	--
	02/19/81	1300	--	--	--	--	--	--	--	--
	03/18/81	1200	--	--	--	--	--	--	--	--
	04/16/81	1530	--	--	--	--	--	--	--	--
	06/02/81	1600	--	--	--	--	--	--	--	--
	07/08/81	1200	--	--	--	--	--	--	--	--
	07/14/81	1200	--	--	--	--	--	--	--	--
	08/25/81	1015	0	2	7	--	80	<1	0	<1
	09/03/81	1030	--	--	--	--	--	--	--	--
	09/24/81	1330	1	--	--	59	--	--	--	--
09306700	04/30/81	0815	--	--	--	50	--	--	--	--
	09/29/81	1000	--	--	--	52	--	--	--	--

STATION NUMBER	DATE	TIME	BORON DISS (UG/L)	BROMIDE DISS (MG/L)	CADMIUM DISS (UG/L)	CADMIUM TOTAL (UG/L)	CADIUM, TOTAL IN BOT-TOM MAT (UG/G)	CHRO-MIUM DISS (UG/L)	CHRO-MIUM, SUS-PENDED RECOV. (UG/L)	CHROM-IUM, TOTAL (UG/L)
09306395	10/06/80	1500	50	--	<1	--	--	20	--	--
	11/21/80	1400	70	--	--	--	--	--	--	--
	02/19/81	1300	50	--	--	--	--	--	--	--
	03/18/81	1200	60	--	--	--	--	--	--	--
	04/16/81	1530	40	--	--	--	--	--	--	--
	06/02/81	1600	20	--	1	--	--	0	--	--
	07/08/81	1200	50	--	--	--	--	--	--	--
	07/14/81	1200	50	--	--	--	--	--	--	--
	08/25/81	1015	60	--	<1	0	1	10	0	0
	09/03/81	1030	100	--	--	--	--	--	--	--
	09/24/81	1330	--	0.03	<1	--	--	0	--	--
09306700	04/30/81	0815	--	0.00	2	--	--	10	--	--
	09/29/81	1000	--	0.00	<1	--	--	0	--	--

TABLE 4.1-8 (CONTINUED). SUMMARY OF WHITE RIVER STATIONS
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

STATION NUMBER	DATE	TIME	CHROMIUM, TOTAL IN BOTTOM MAT (UG/G)	COBALT, TOTAL IN BOTTOM MAT (UG/G)	COPPER DISS (UG/L)	COPPER, SUSPENDED RECOVERABLE (UG/L)	COPPER, TOTAL (UG/L)	COPPER, TOTAL IN BOTTOM MATERIAL (UG/G)	CYANIDE TOTAL (MG/L)	IRON DISS (UG/L)
09306395	10/06/80	1500	--	--	2	--	--	--	--	<10
	11/21/80	1400	--	--	--	--	--	--	--	--
	02/19/81	1300	--	--	--	--	--	--	--	--
	03/18/81	1200	--	--	--	--	--	--	--	--
	04/16/81	1530	--	--	--	--	--	--	--	100
	06/02/81	1600	--	--	6	--	--	--	--	--
	07/08/81	1200	--	--	--	--	--	--	--	40
	07/14/81	1200	--	--	--	--	--	--	--	--
	08/25/81	1015	3	10	5	3	8	15	0.00	<10
	09/03/81	1030	--	--	--	--	--	--	--	--
	09/24/81	1330	--	--	4	--	--	--	--	--
09306700	04/30/81	0815	--	--	29	--	--	--	--	--
	09/29/81	1000	--	--	130	--	--	--	--	--

STATION NUMBER	DATE	TIME	IRON TOTAL (AS FE) (UG/L)	IRON, TOTAL IN BOTTOM MAT (UG/G)	LEAD DISS (UG/L)	LEAD, SUSPENDED RECOVERABLE (UG/L)	LEAD, TOTAL (UG/L)	LEAD, TOTAL IN BOTTOM MATERIAL (UG/G)	LITHIUM DISS (UG/L)	LITHIUM SUSPENDED RECOVERABLE (UG/L)
09306395	10/06/80	1500	--	--	0	--	--	--	--	--
	11/21/80	1400	--	--	--	--	--	--	--	--
	02/19/81	1300	--	--	--	--	--	--	--	--
	03/18/81	1200	--	--	--	--	--	--	--	--
	04/16/81	1530	--	--	--	--	--	--	--	--
	06/02/81	1600	--	--	2	--	--	--	--	--
	07/08/81	1200	--	--	--	--	--	--	--	--
	07/14/81	1200	--	--	--	--	--	--	--	--
	08/25/81	1015	2200	3200	0	4	4.0	10	24	0
	09/03/81	1030	--	--	--	--	--	--	--	--
	09/24/81	1330	--	--	7	--	--	--	17	--

TABLE 4.1-8 (CONTINUED). SUMMARY OF WHITE RIVER STATIONS
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

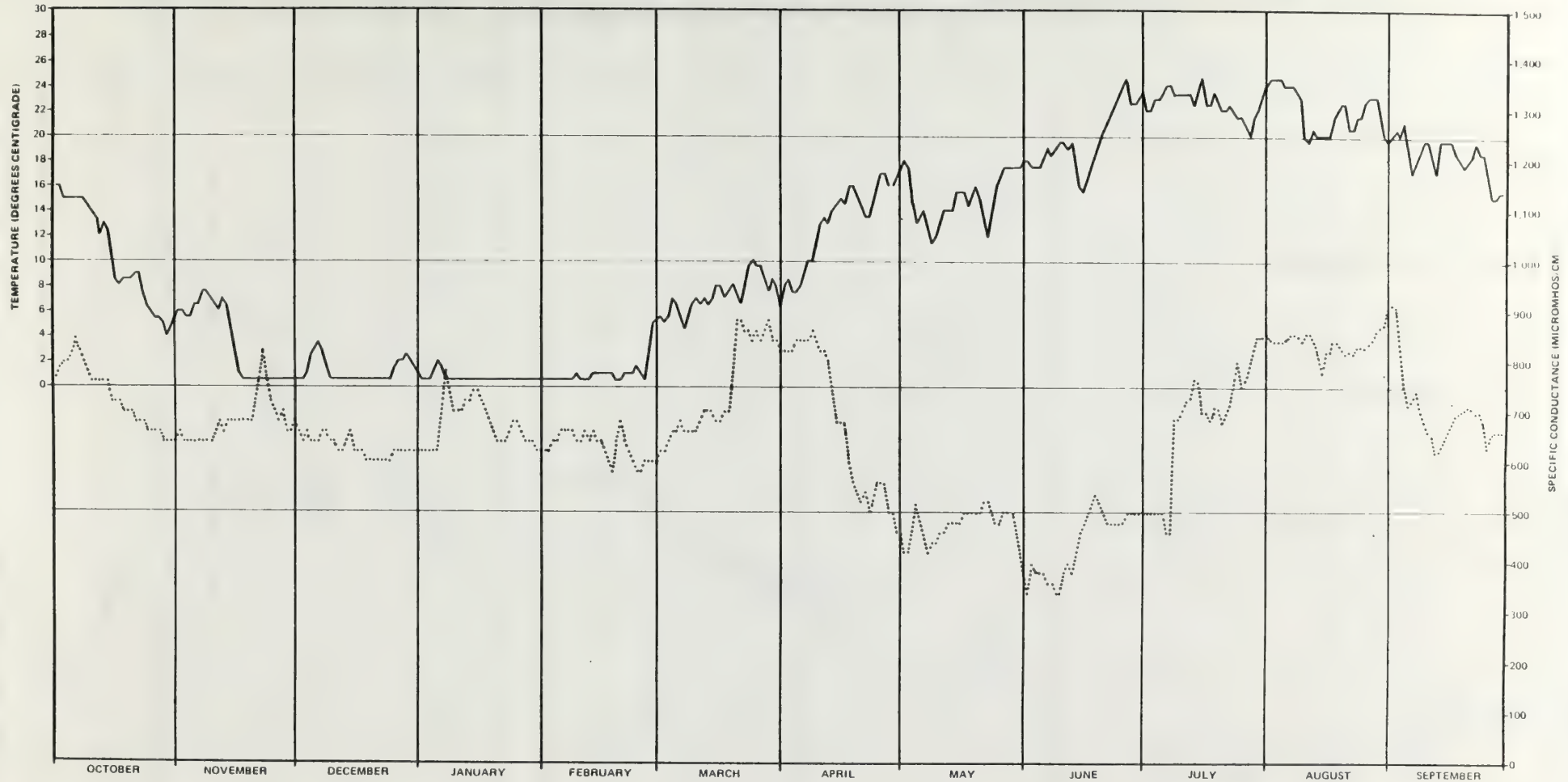
STATION NUMBER	DATE	TIME	LITHIUM TOTAL (UG/L)	MANGANESE DISS (UG/L)	MANGANESE SUSPENDED RECOV. (UG/L)	MANGANESE, TOTAL (UG/L)	MANGANESE, TOTAL IN BOTTOM MAT (UG/G)	MERCURY DISS (UG/L)	MERCURY SUSPENDED RECOVERABLE (UG/L)	MERCURY TOTAL (UG/L)
09306395	10/06/80	1500	--	2	--	--	--	0.0	--	--
	11/21/80	1400	--	--	--	--	--	--	--	--
	02/19/81	1300	--	--	--	--	--	--	--	--
	03/18/81	1200	--	--	--	--	--	--	--	--
	04/16/81	1530	--	9	--	--	--	--	--	--
	06/02/81	1600	--	--	--	--	--	0.0	--	--
	07/08/81	1200	--	4	--	--	--	--	--	--
	07/14/81	1200	--	--	--	--	--	--	--	--
	08/25/81	1015	20	4	60	60	200	0.0	0.0	0.0
	09/03/81	1030	--	--	--	--	--	--	--	--
	09/24/81	1330	--	--	--	--	--	0.0	--	--
09306700	04/30/81	0815	--	--	--	--	--	1.1	--	--
	09/29/81	1000	--	--	--	--	--	0.0	--	--

STATION NUMBER	DATE	TIME	MERCURY TOTAL IN BOTTOM MAT (UG/G)	METHYL. BLUE ACTIVE SUBSTAN (MBAS) (MG/L)	MOLYBDENUM DISS (UG/L)	MOLYBDENUM, TOTAL (UG/L)	MOLYBDENUM, TOTAL IN BOTTOM MAT (UG/G)	NICKEL DISS (UG/L)	NICKEL, SUSPENDED RECOVERABLE (UG/L)	NICKEL, TOTAL (UG/L)
09306395	10/06/80	1500	--	--	--	--	--	--	--	--
	11/21/80	1400	--	--	--	--	--	--	--	--
	02/19/81	1300	--	--	--	--	--	--	--	--
	03/18/81	1200	--	--	--	--	--	--	--	--
	04/16/81	1530	--	--	--	--	--	--	--	--
	06/02/81	1600	--	--	--	--	--	--	--	--
	07/08/81	1200	--	--	--	--	--	--	--	--
	07/14/81	1200	--	--	--	--	--	--	--	--
	08/25/81	1015	0.02	0.00	<10	4	<1	4	0	4
	09/03/81	1030	--	--	--	--	--	--	--	--
	09/24/81	1330	--	--	<10	--	--	--	--	--
09306700	04/30/81	0815	--	--	<10	--	--	--	--	--
	09/29/81	1000	--	--	<10	--	--	--	--	--

TABLE 4.1-8 (CONTINUED). SUMMARY OF WHITE RIVER STATIONS
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

STATION NUMBER	DATE	TIME	NICKEL, TOTAL IN BOTTOM MAT (UG/G)	PHENOLS (UG/L)	SELENIUM DISS (UG/L)	SELENIUM, SUSPENDED TOTAL (UG/L)	SELENIUM, TOTAL (UG/L)	SELENIUM, TOTAL IN BOTTOM MAT (UG/G)	STRONTIUM DISS (UG/L)	SULFIDE TOTAL (MG/L)
09306395	10/06/80	1500	--	--	1	--	--	--	--	--
	11/21/80	1400	--	--	--	--	--	--	--	--
	02/19/81	1300	--	--	--	--	--	--	--	--
	03/18/81	1200	--	--	--	--	--	--	--	--
	04/16/81	1530	--	--	--	--	--	--	--	--
	06/02/81	1600	--	--	1	1	--	--	--	--
	07/08/81	1200	--	--	--	--	--	--	--	--
	07/14/81	1200	--	--	--	--	--	--	--	--
	08/25/81	1015	10	0	1	0	1	0	--	--
	09/03/81	1030	--	--	--	--	--	--	--	--
	09/24/81	1330	--	0	1	--	--	--	810	0.1
09306700	04/30/81	0815	--	1	1	--	--	--	560	0.3
	09/29/81	1000	--	1	1	--	--	--	880	0.2

STATION NUMBER	DATE	TIME	VANADIUM DISS (UG/L)	ZINC DISS (UG/L)	ZINC, TOTAL (UG/L)	ZINC, TOTAL IN BOTTOM MAT (UG/G)
09306395	10/06/80	1500	--	<3	--	--
	11/21/80	1400	--	--	--	--
	02/19/81	1300	--	--	--	--
	03/18/81	1200	--	--	--	--
	04/16/81	1530	--	--	--	--
	06/02/81	1600	--	30	--	--
	07/08/81	1200	--	--	--	--
	07/14/81	1200	--	--	--	--
	08/25/81	1015	0.00	<3	20	17
	09/03/81	1030	--	--	--	--
	09/24/81	1330	1.0	9	--	--
09306700	04/30/81	0815	13	370	--	--
	09/29/81	1000	1.0	7	--	--

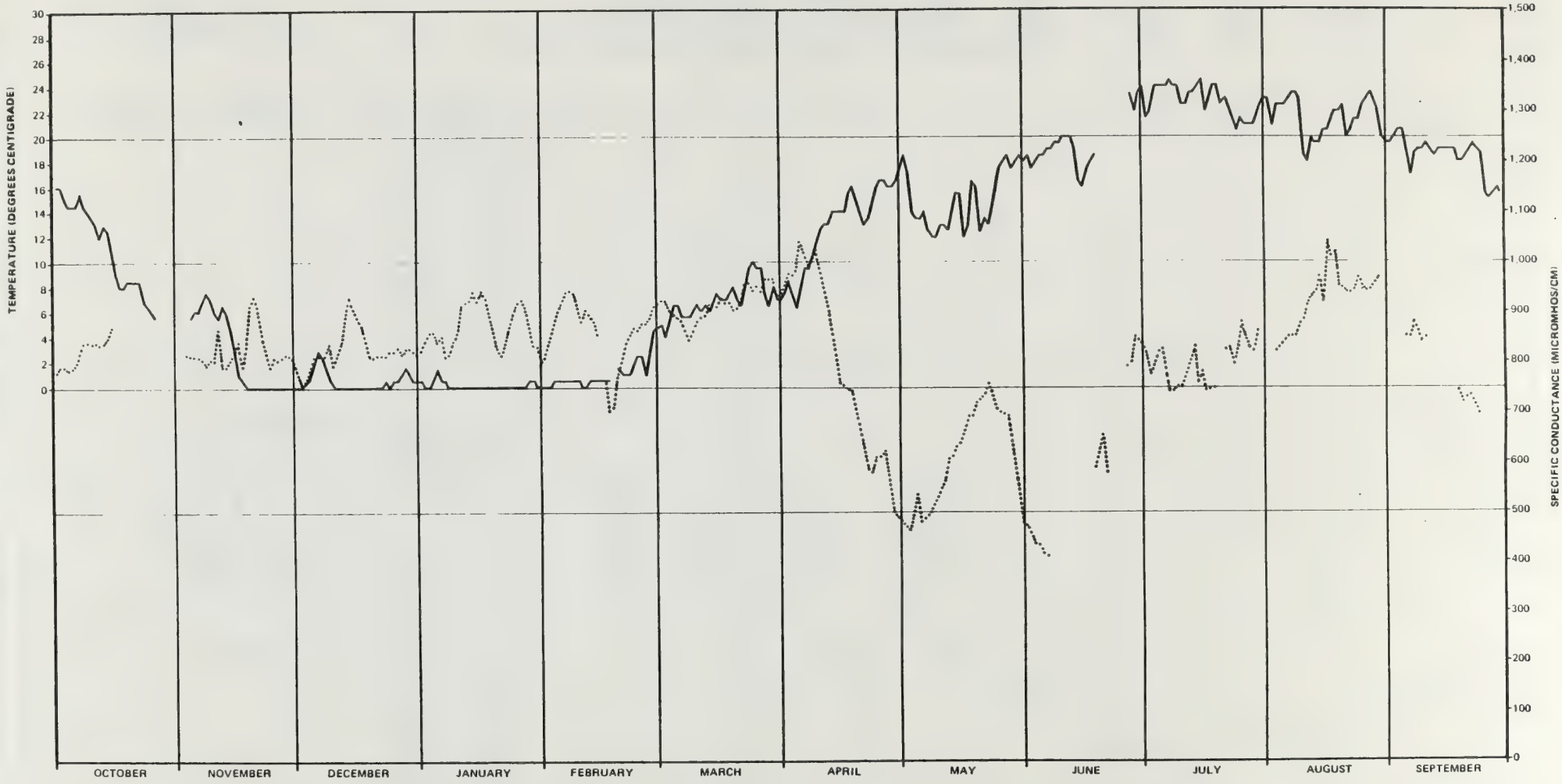


WHITE RIVER NEAR COLORADO STATE LINE, UTAH (Sta. 09306395)

MEAN DAILY TEMPERATURE AND SPECIFIC CONDUCTANCE

OCTOBER 1980 – SEPTEMBER 1981

FIGURE 4 1 4



LEGEND

TEMPERATURE

SPECIFIC CONDUCTANCE

WHITE RIVER BELOW ASPHALT WASH, NEAR WATSON, UTAH (Sta. 09306700)

MEAN DAILY TEMPERATURE AND SPECIFIC CONDUCTANCE

OCTOBER 1980 – SEPTEMBER 1981

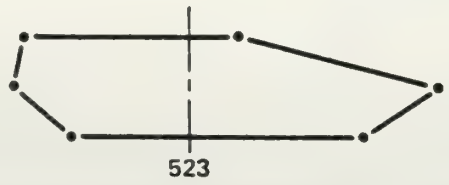
FIGURE 4.1-5

generally higher during the winter than during the remainder of the year. The minimum value during the year was 6.6 m/gl at station 6395 on July 14.

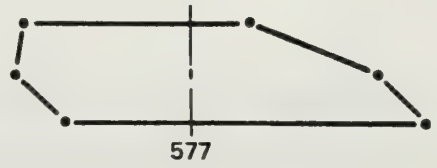
The concentration of dissolved solids generally followed an inverse relationship to the amount of streamflow, ranging from 241 mg/l during upper basin runoff to 620 mg/l during late summer baseflow. However, in the past there normally has been an exception to this relationship where, when lower basin runoff was a dominant source of streamflow, the dissolved solids concentration increased as the amount of streamflow increased. The 1981 laboratory water quality data did not illustrate this trend. The most likely reasons for this are: 1) the February 19 sample was collected during a period of unusually rapid melting of the snowpack in the lower basin so that the time of contact between the soils and the runoff was less than usual, and 2) the March 18 and April 16 samples were collected during a period when lower basin runoff was occurring, but was not the dominant source of flow. Inspection of the continuous streamflow and specific conductance records between March 18 and April 16 (a period during which a significant amount of lower basin runoff occurred) indicated that specific conductance did increase as streamflow increased.

The distribution of major ions for selected representative samples is shown in Figure 4.1-6. These Stiff diagrams illustrate the variations of the major ions in comparison to the dissolved solids concentration and the source of streamflow. For example, during fall baseflow, calcium and sodium were the dominant cations, while

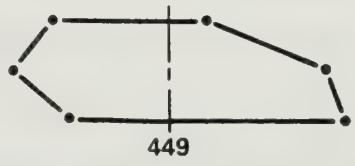
FALL BASEFLOW
November 21, 1980



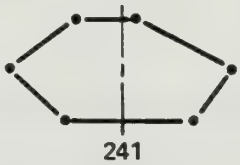
BASEFLOW AND LOWER BASIN RUNOFF
March 18, 1981



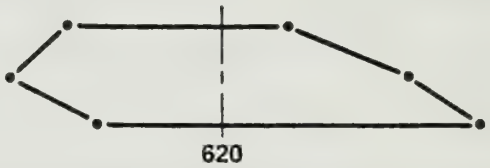
LOWER AND UPPER BASIN RUNOFF
April 16, 1981

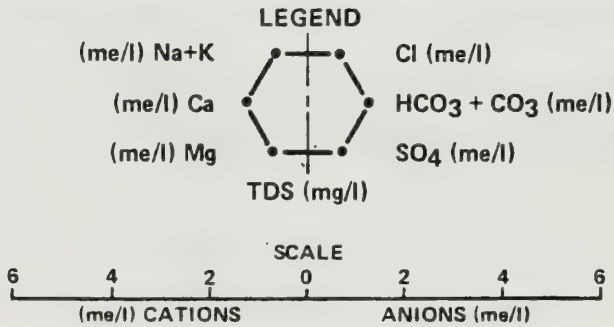


UPPER BASIN RUNOFF
June 2, 1981



SUMMER BASEFLOW
September 3, 1981





DISTRIBUTION OF MAJOR IONS FOR THE WHITE RIVER STATION 09306395

OCTOBER 1980 – SEPTEMBER 1981

FIGURE 4.1-6

bicarbonate plus carbonate (as represented by total alkalinity) were the dominant anions. However, during the period when lower basin runoff contributed to streamflow, the relative proportion of sulfate increased significantly in comparison to the fall baseflow sample. During upper basin runoff, calcium and bicarbonate plus carbonate were the dominant ions. When late summer baseflow occurred, which is also the irrigation season, calcium and sulfate were the dominant ions. This is shown by the results of the September 3 sample. The influence of irrigation tailwater returned to the White River was largely responsible for the differences in the distribution of major ions between late summer and fall baseflow samples. The concentrations of individual major ions generally followed an inverse relationship to the amount of streamflow, similar to the trend for dissolved solids.

Generally, the concentrations of the above nutrients (nitrogen and phosphorus compounds) increased during runoff due to transportation of organic matter into the river (Table 4.1-8). Thereafter, the concentrations decreased over a relatively short time period through biological activity. For example, the concentration of dissolved ammonia was greater during upper basin runoff (0.130 mg/l) than during summer baseflow (0.030 to 0.060 mg/l). Similarly, dissolved nitrite plus nitrate values were relatively low (0.15 mg/l or less) throughout the year with the higher values occurring during or immediately following periods of increased streamflow. Total phosphorus concentration was considerably greater during upper basin runoff (0.270 mg/l) than during late summer baseflow (0.030 mg/l). Dissolved ortho-phosphorus

values were low (0.010 mg/l or less) except for a value of 0.070 mg/l on July 8, which was recorded immediately following a period of increased streamflow.

Values of chemical oxygen demand (COD) were variable, ranging from 24 to 48 mg/l. The concentrations of dissolved organic carbon (DOC) ranged from 3.3 to 8.5 mg/l. The maximum values for both parameters were from the April 30 sample at station 6700 which was collected during increasing streamflow due to upper basin snowmelt. Analysis for DOC was inadvertently omitted for the June 2 sample at station 6395.

The data for the trace elements are presented in Table 4.1-8. Most of the values for the dissolved phase of these parameters were relatively low and/or similar to values collected during previous years. This discussion will concentrate on those values which were unusual as compared to previously collected data.

The concentration of dissolved copper (130 ug/l) for the sample collected on September 29 at station 6700 was relatively high compared to most of the data collected during the period of record for the White River stations. However, this value is not greater than the maximum for the period of record (340 ug/l on March 3, 1975 at station 6700), and there are several other values from the period of record ranging from 110 to 160 ug/l. Most of the higher values from the previous record appear to have occurred immediately following large flow contributions from Evacuation Creek. The data collected at stations 6400, 6500, 6600 and 6700 on the White River and station 6430 on Evacuation

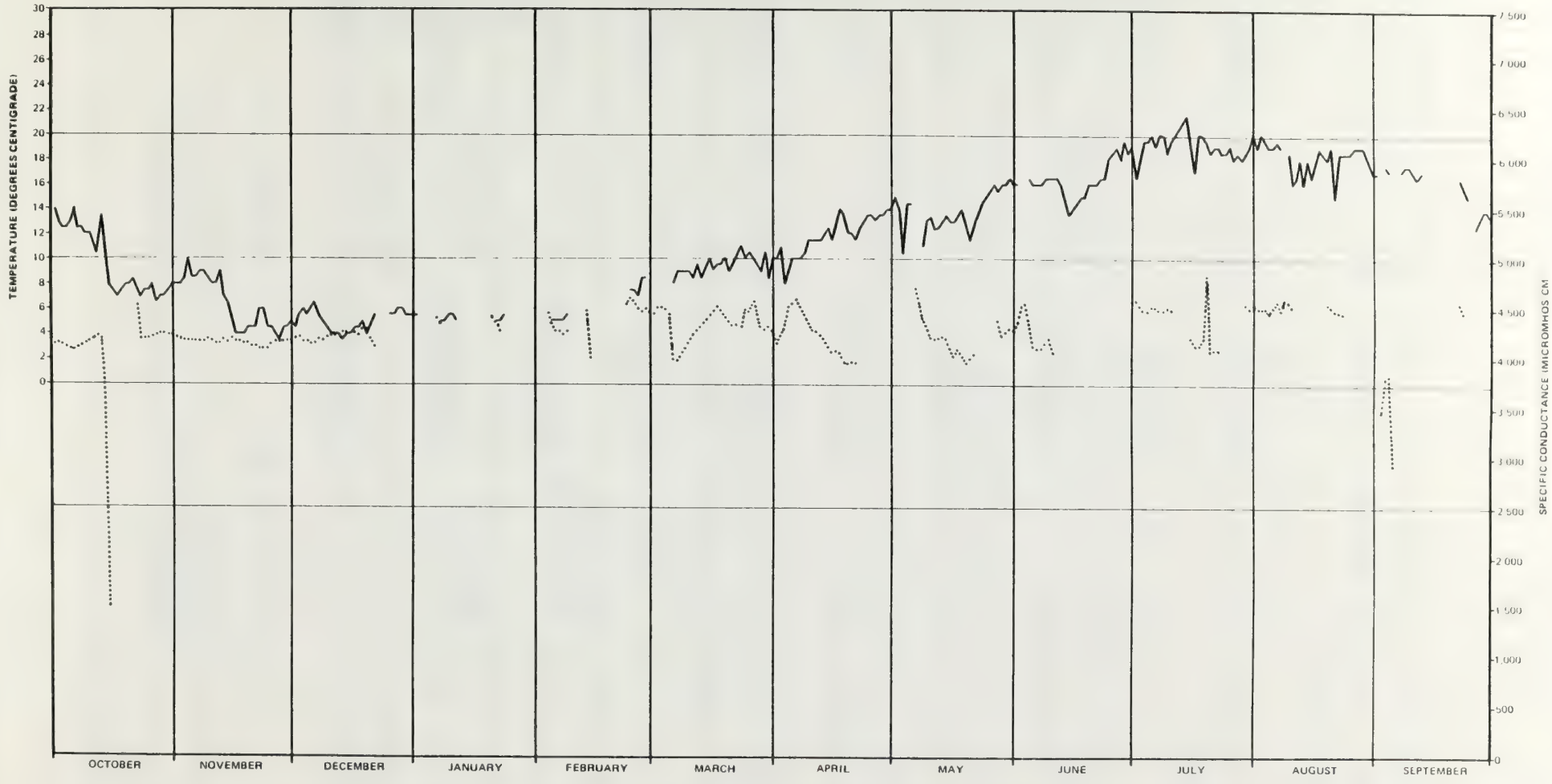
Creek on March 3 and 4, 1975 indicate that the dissolved copper in the flow from Evacuation Creek caused a temporary increase in downstream copper concentrations. A similar situation occurred when a large flow event was recorded at station 6430 on September 24, 1981, only a few days prior to collection of the sample at station 6700 on September 29. Again, the rise in dissolved copper concentration at station 6700 was probably due to the effects of this flow event from Evacuation Creek. Sediment contributions associated with the event could account for the elevated concentration of dissolved copper a few days after the water would have passed station 6700.

Data from the April 30 sample collected at station 6700 indicated that several trace metals were at high levels as compared to data from the period of record. The concentrations of dissolved aluminum, lead, mercury, vanadium and zinc were 460, 48, 1.1, 13.0 and 370 ug/l, respectively. Maximum values from the period of record prior to 1981 for these five trace metals were 160, 17, <0.5, 10 and 420 ug/l, respectively. All of the April 30 sample values given above were greater than the maximum values for the prior period of record, except the value for dissolved zinc. The cause for these high values is not known. It is not likely that they were due to flow contributions from Evacuation Creek because streamflow was quite small at that time in comparison to the White River, and also because water quality data for station 6430 during the period of record do not indicate that Evacuation Creek has ever had similar high concentrations of these five

trace metals. Neither Asphalt Wash nor Southam Canyon exhibited any runoff during this time period, so they also would not be a cause for such increases in the White River. Therefore, it is most likely that the elevated levels of these five trace metals for the April 30 sample were caused by runoff or discharges within the White River drainage basin upstream of this project.

Table 4.1-8 includes data collected by the USGS on the suspended and total phases of certain trace elements in the water, as well as on amounts recoverable from bottom material. Discussion of these data will be presented in a later report which will describe conclusions from the entire baseline data record for this project.

Evacuation Creek. The continuous records of mean daily temperature and specific conductance for station 6430 are shown in Figure 4.1-7. The mean daily temperature during the winter was somewhat higher than in previous years due to a mild winter and the influence of flow contribution from a spring just upstream of the station. The recorded instantaneous temperature values during the year ranged from a low of 1.5 to a high of 32.5°C. The range of recorded instantaneous specific conductance values was from 620 micromhos/cm (on October 15) to 7,320 micromhos/cm (on July 19). The minimum value occurred during the peak of runoff from a thunderstorm. The maximum value occurred during the initial rising portion of runoff from another thunderstorm. All of these extreme values for temperature and specific conductance were within the observed ranges from the period of record prior to 1981. Data from the period of record for this station indicated that,



EVACUATION CREEK NEAR MOUTH, NEAR WATSON, UTAH (Sta. 09306430)

MEAN DAILY TEMPERATURE AND SPECIFIC CONDUCTANCE

OCTOBER 1980 – SEPTEMBER 1981

FIGURE 4.1.7

during thunderstorm runoff, an initial rise in specific conductance due to flushing of salts is followed by reduced values due to a dilution of natural baseflow.

The 1981 field water quality data for station 6430 are presented in Table 4.1-7.

The values of pH were relatively stable, with the exception of a value of 9.8 on December 2. The rest of the values during the year ranged from 7.6 to 8.6. The cause of the high value on December 2 is not clear, but it may be related to the flow contribution of local ground water discharge. The concentration of dissolved oxygen was variable, ranging from 6.4 to 11.5 mg/l.

It should be noted that all of the laboratory water quality data presented in Table 4.1-9 were from samples collected while streamflow was less than 1 cfs. Therefore, none of these data represented a high streamflow period. This can be seen in the consistency of the values for dissolved solids, alkalinity, hardness and the major ions which were at levels which are representative of the baseflow regime at this station. The amount of snowmelt runoff occurring at the time that the April 30 sample was collected was not of sufficient magnitude to have a dominant effect on water quality, as represented by the above parameters.

The data for the major ions indicate that sodium and sulfate were the dominant ions for all of the samples. Concentrations of dissolved solids and the major ions were similar to the average values

TABLE 4.1-9. EVACUATION CREEK NEAR MOUTH (09306430)
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	TOTAL DISS SOLIDS (SUM) (MG/L)	CALCIUM DISS (MG/L)	MAGNE-SIUM DISS (MG/L)	POTAS-SIUM DISS (MG/L)	SODIUM DISS (MG/L)	BICAR-BONATE (MG/L)	CHLOR-IDE DISS (MG/L)	SUL-FATE DISS (MG/L)	FLUOR-IDE DISS (MG/L)	SILICA DISS (MG/L)
01/29/81	1210	3610	190	170	7.1	730	500	53	2200	0.8	10
04/30/81	0915	3620	190	170	8.1	750	475	40	2200	0.9	11
07/29/81	1100	3760	200	170	9.0	770	500	51	2300	0.7	12
08/25/81	1010	3710	180	170	9.0	750	463	50	2300	0.4	15
09/30/81	0930	3760	190	170	7.6	760	512	55	2300	0.8	16

DATE	TIME	ALKALI-NITY, LAB (MG/L AS CACO3)	HARD-NESS TOTAL (AS CACO3) (MG/L)	HARD-NESS, NONCAR. (AS CACO3) (MG/L)	SODIUM ADSORP RATIO (SAR)	PERCENT SODIUM	OXYGEN DEMAND, CHEM (HIGH LEVEL) (MG/L)	ORGANIC CARBON DISS (MG/L)	OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG/L)	AMMONIA DISS (AS N) (MG/L)	NITRITE DISS (AS N) (MG/L)
01/29/81	1210	410	1200	760	9.3	57	--	--	--	--	--
04/30/81	0915	390	1200	784	9.5	58	--	17	--	0.120	--
07/29/81	1100	410	1200	789	9.7	58	--	--	--	--	--
08/25/81	1010	380	1200	769	9.6	58	66	12	0	0.140	0.030
09/30/81	0930	420	1200	754	9.7	58	58	13	--	0.150	--

TABLE 4.1-9 (CONTINUED). EVACUATION CREEK NEAR MOUTH (09306430)
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	NITRATE DISS (AS N) (MG/L)	NITRITE PLUS NITRATE DISS (AS N) (MG/L)	NITRO-GEN, ORGANIC DISS (AS N) (MG/L)	AMMONIA + ORG NITRO TOTAL (AS N) (MG/L)	NITRO-GEN DISS (AS N) (MG/L)	PHOS-PHORUS DISS. (AS P) (MG/L)	PHOS-PHORUS, TOTAL (AS P) (MG/L)	PHOS-PHORUS, ORTHO DISS (AS P) (MG/L)	ALUM-INUM DISS (UG/L)	ALUM-INUM, SUS-PENDED RECOV. (UG/L)
01/29/81	1210	--	0.90	--	--	--	--	--	0.010	--	--
04/30/81	0915	--	1.1	--	2.1	--	--	0.020	0.010	0	--
07/29/81	1100	--	0.65	--	--	--	--	--	0.060	--	--
08/25/81	1010	0.79	0.82	0.49	--	1.5	0.010	--	0.010	10	7800
09/30/81	0930	--	0.77	--	0.85	--	--	0.040	0.030	20	--

DATE	TIME	ALUM-INUM, TOTAL (UG/L)	ARSENIC DISS (UG/L)	ARSENIC SUS-PENDED TOTAL (UG/L)	ARSENIC TOTAL (UG/L)	ARSENIC TOTAL IN BOT-TOM MA-TERIAL (UG/G)	BARIUM DISS (UG/L)	BARIUM, TOTAL IN BOT-TOM MAT (UG/G)	BERYL-LIUM DIS-OLVED (UG/L)	BERYL-LIUM, SUS-PENDED (UG/L)	BERYL-LIUM, TOTAL (UG/L)
01/29/81	1210	--	--	--	--	--	--	--	--	--	--
04/30/81	0915	--	1	--	--	--	200	--	--	--	--
07/29/81	1100	--	--	--	--	--	--	--	--	--	--
08/25/81	1010	7800	3	1	4	9	--	300	0	0	0
09/30/81	0930	--	2	--	--	--	0	--	--	--	--

TABLE 4.1-9 (CONTINUED). EVACUATION CREEK NEAR MOUTH (09306430)
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	BERYLLIUM, TOTAL IN BOTTOM MAT (UG/G)	BORON DISS (UG/L)	BROMIDE DISS (MG/L)	CADMIUM DISS (UG/L)	CADMIUM SUSPENDED (UG/L)	CADMIUM TOTAL (UG/L)	CADIUM, TOTAL IN BOTTOM MAT (UG/G)	CHROMIUM DISS (UG/L)	CHROMIUM, SUSPENDED RECOV. (UG/L)	CHROMIUM, TOTAL (UG/L)
01/29/81	1210	--	1700	--	--	--	--	--	--	--	--
04/30/81	0915	--	1600	0.20	0	--	--	--	10	--	--
07/29/81	1100	--	1700	--	--	--	--	--	--	--	--
08/25/81	1010	<1	1600	--	0	0	0	1	10	10	20
09/30/81	0930	--	1600	0.20	0	--	--	--	0	--	--

DATE	TIME	CHROMIUM, TOTAL IN BOTTOM MAT (UG/G)	COBALT, TOTAL IN BOTTOM MAT (UG/G)	COPPER DISS (UG/L)	COPPER, SUSPENDED RECOVERABLE (UG/L)	COPPER, TOTAL (UG/L)	COPPER, TOTAL IN BOTTOM MATERIAL (UG/G)	CYANIDE TOTAL (MG/L)	IRON DISS (UG/L)	IRON TOTAL (AS FE) (UG/L)	IRON, TOTAL IN BOTTOM MAT (UG/G)
01/29/81	1210	--	--	--	--	--	--	--	50	--	--
04/30/81	0915	--	--	24	--	--	--	--	50	--	--
07/29/81	1100	--	--	--	--	--	--	--	50	--	--
08/25/81	1010	8	10	6	25	31	10	0.00	40	14000	6500
09/30/81	0930	--	--	15	--	--	--	--	110	--	--

TABLE 4.1-9 (CONTINUED). EVACUATION CREEK NEAR MOUTH (09306430)
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	LEAD DISS (UG/L)	LEAD, SUS-PENDED RECOV-ERABLE (UG/L)	LEAD, TOTAL (UG/L)	LEAD, TOTAL IN BOT-TOM MA-TERIAL (UG/G)	LITHIUM DISS (UG/L)	LITHIUM SUS-PENDED RECOV-ERABLE (UG/L)	LITHIUM TOTAL (UG/L)	MAN-GANESE DISS (UG/L)	MAN-GANESE SUS-PENDED RECOV. (UG/L)	MANGAN-ESE, TOTAL (UG/L)
01/29/81	1210	--	--	--	--	--	--	--	80	--	--
04/30/81	0915	2	--	--	--	110	--	--	90	--	--
07/29/81	1100	--	--	--	--	--	--	--	180	--	--
08/25/81	1010	1	10	11	10	120	10	130	170	270	440
09/30/81	0930	0	--	--	--	120	--	--	240	--	--

DATE	TIME	MANGAN-ESE, TOTAL IN BOT-TOM MAT (UG/G)	MERCURY DISS (UG/L)	MERCURY SUS-PENDED RECOV-ERABLE (UG/L)	MERCURY TOTAL (UG/L)	MERCURY TOTAL IN BOT-TOM MAT (UG/G)	METHYL. BLUE ACTIVE SUBSTAN (MBAS) (MG/L)	MOLYB-DENUM DISS (UG/L)	MOLYB-DENUM, SUS-PENDED (UG/L)	MOLYB-DENUM, TOTAL (UG/L)	MOLYB-DENUM, TOTAL IN BOT-TOM MAT (UG/G)
01/29/81	1210	--	--	--	--	--	--	--	--	--	--
04/30/81	0915	--	0.0	--	--	--	--	42	--	--	--
07/29/81	1100	--	--	--	--	--	--	--	--	--	--
08/25/81	1010	440	0.0	0.1	0.1	0.02	0.10	4	21	25	<1
09/30/81	0930	--	0.0	--	--	--	--	38	--	--	--

TABLE 4.1-9 (CONTINUED). EVACUATION CREEK NEAR MOUTH (09306430)
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	NICKEL DISS (UG/L)	NICKEL, SUS-PENDED RECOV-ERABLE (UG/L)	NICKEL, TOTAL (UG/L)	NICKEL, TOTAL IN BOT-TOM MAT (UG/G)	PHENOLS (UG/L)	SELE-NIUM DISS (UG/L)	SELE-NIUM, SUS-PENDED TOTAL (UG/L)	SELEN-IUM, TOTAL (UG/L)	SELEN-IUM, TOTAL IN BOT-TOM MAT (UG/G)	STRON-TIUM DISS (UG/L)
01/29/81	1210	--	--	--	--	--	--	--	--	--	--
04/30/81	0915	--	--	--	--	1	0	--	--	--	4000
07/29/81	1100	--	--	--	--	--	--	--	--	--	--
08/25/81	1010	1	13	14	11	0	2	0	2	0	--
09/30/81	0930	--	--	--	--	--	2	--	--	--	3800

DATE	TIME	SULFIDE TOTAL (MG/L)	VANA-DIUM DISS (UG/L)	ZINC DISS (UG/L)	ZINC, SUS-PENDED (UG/L)	ZINC, TOTAL (UG/L)	ZINC, TOTAL IN BOT-TOM MAT (UG/G)
01/29/81	1210	--	--	--	--	--	--
04/30/81	0915	0.5	2.0	20	--	--	--
07/29/81	1100	--	--	--	--	--	--
08/25/81	1010	--	0.00	10	50	60	20
09/30/81	0930	0.2	1.0	30	--	--	--

for baseflow from the previous years of record. One exception to this trend is that the concentration of dissolved silica on August 25 and September 30, 1981 (15 and 16 mg/l) was slightly above the maximum value from the previous period of record (14 mg/l). The cause of this is not presently known.

The concentrations of dissolved ammonia in the August 25 and September 30, 1981 samples (0.140 and 0.150 mg/l) were slightly above the maximum value from the previous period of record (0.12 mg/l). The concentrations of dissolved nitrite plus nitrate ranged from 0.65 to 1.1 mg/l, and total ammonia plus organic nitrogen ranged from 0.85 to 2.1 mg/l during the year. Neither of these two parameters were above the maximum values from the previous period of record. Dissolved orthophosphorus concentrations ranged from 0.010 to 0.060 mg/l during the year. The July 29 value (0.060 mg/l) was slightly greater than the maximum value from the previous period of record (0.04 mg/l). The concentration of total phosphorus was relatively low on April 30 (0.020 mg/l) and September 30 (0.040 mg/l). Total phosphorus was not analyzed in the July 29 sample. The cause for the higher concentrations of dissolved ammonia and orthophosphorus is not clear, but is probably related to the relatively frequent occurrence of thunderstorm runoff from June through September. Such runoff would transport organic matter into Evacuation Creek.

Values of chemical oxygen demand (COD) and dissolved organic carbon (DOC) were at levels similar to previous years. The concentrations of trace elements were also at levels similar to previous years.

Table 4.1-9 includes data collected by the USGS on the suspended and total phases of certain trace elements, as well as on amounts recoverable from bottom material. Discussion of these data will be presented in a later report.

Dry Washes. No water quality samples were collected during the year at stations 6602, 6610 and 6625. No flows occurred at stations 6602 and 6610. The USGS did collect a bed material sample on August 25 at station 6625, and analyses were conducted for the recoverable amounts of certain trace elements (Table 4.1-10). The data presented will be discussed in a later report.

4.1.1.4 Conclusions

White River

The 1981 total annual runoff for stations 6395 and 6700 was considerably less than the historic average annual runoff based on the record at station 6500 (337,200 acre-feet and 319,600 acre-feet versus 503,500 acre-feet). In fact, the 1981 mean discharge for both stations was well below the twenty-fifth percentile of the annual mean discharge values from 1924 through 1979 water years at station 6500. Only the 1977 and 1934 water years of this historic record had an annual mean discharge less than that for the 1981 water year. The annual peak discharge at stations 6395 and 6700 was also very low in comparison to the historic record for station 6500. There was a decrease (5.2%) in total annual runoff between station 6395 (upstream of the tracts) and station 6700 (downstream of the tracts). The decrease in streamflow

TABLE 4.1-10. ASPHALT WASH NEAR MOUTH (09306625)
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	ARSENIC TOTAL IN BOTTOM MATERIAL (UG/G)	BARIUM, TOTAL IN BOTTOM MAT (UG/G)	BERYLLIUM, TOTAL IN BOTTOM MAT (UG/G)	CADIUM, TOTAL IN BOTTOM MAT (UG/G)	CHROMIUM, TOTAL IN BOTTOM MAT (UG/G)	COBALT, TOTAL IN BOTTOM MAT (UG/G)	COPPER, TOTAL IN BOTTOM MATERIAL (UG/G)	IRON, TOTAL IN BOTTOM MAT (UG/G)	LEAD, TOTAL IN BOTTOM MATERIAL (UG/G)	MANGANESE, TOTAL IN BOTTOM MAT (UG/G)
08/25/81	1430	10	300	<1	<1	20	10	10	8500	10	330

DATE	TIME	MERCURY TOTAL IN BOTTOM MAT (UG/G)	MOLYBDENUM, TOTAL IN BOTTOM MAT (UG/G)	NICKEL, TOTAL IN BOTTOM MAT (UG/G)	SELENIUM, TOTAL IN BOTTOM MAT (UG/G)	ZINC, TOTAL IN BOTTOM MAT (UG/G)
08/25/81	1430	0.01	<1	11	0	31

was greatest during the period January through July 1981. The reasons for this apparent loss in streamflow are not clear at the present time.

The total 1981 suspended sediment discharge at White River station 6395 was also considerably less than has been recorded annually from 1978 to 1980. This was due primarily to the reduced runoff of 1981. Instantaneous sediment concentrations at both stations 6395 and 6700 were within the range of concentrations observed in previous sampling years.

In general, the water quality parameters for stations 6395 and 6700 were at levels similar to the levels observed in earlier years. However, there were certain important exceptions. For example, trace metal constituents were present in one sample at concentrations that were considerably higher than had been observed in earlier monitoring periods. It is not probable that this was caused by discharges from the tract drainages. Instead, it is more likely that the cause of these higher concentrations was related to a discharge or runoff source located in the White River drainage basin upstream of the tracts.

The 1981 water quality records at stations 6395 and 6700 indicated little difference in water quality between these two stations for most days of the year. Short-term differences were seen whenever flash floods occured in one or more tributaries between the stations. This was most noticeable in the continuous specific conductance records. For example, flow contributions from Evacuation Creek on August 14 and 16 caused an increase in the maximum recorded specific conductance on

both dates at the downstream station (1420 and 1370 micromhos/cm) as compared to the upstream station (797 and 840 micromhos/cm).

Evacuation Creek

The 1981 total annual runoff was slightly less than the average annual runoff at station 6430 over the previous six years of record (906 acre-feet versus 1,156 acre-feet). The length of record is too short to accurately determine the "normal" annual runoff for this drainage. Inspection of the streamflow records indicated that, in the 1981 water year, the amount of runoff from snowmelt was somewhat less than in most of the prevous years, while the amount from thunderstorm runoff was somewhat greater. The peak flow during the 1981 water year was considerably less than the maximum from the previous period of record (380 cfs versus 1,980 cfs).

The instantaneous suspended sediment concentrations collected during winter baseflow at Evacuation Creek during 1981 were much lower than sampled in 1980. No clear cause for this decrease was apparent, although construction activities upstream of tracts Ua-Ub during 1980 may be responsible. The maximum instantaneous sediment concentration during 1981 was within the range of concentrations observed during previous years.

In general, the water quality parameters for station 6430 during the 1981 water year were at levels similar to those observed during previous monitoring years. There were exceptions for three constituents (dissolved silica, ammonia, and orthophosphorus), which exhibited

a few values slightly above previous maximum values. These were not believed to be indicative of any trend relating to the water quality of Evacuation Creek. It is more likely that they were caused by the hydrologic system's response to natural variations in climatic conditions.

Dry Washes

The 1981 water year was the first year of record for station 6602 in the proposed plant site drainge. No flow events occurred during the monitoring period, so no conclusions were drawn concerning this drainage.

Station 6610 at the mouth of Southam Canyon also had no flow during the 1981 water year. This was somewhat unusual since there had been flow in each of the six previous monitoring years. It was not possible to draw any further conclusions concerning the 1981 annual runoff record since the period of record is very short.

The total annual runoff for station 6625 near the mouth of Asphalt Wash was less than the average annual runoff for the previous six years of record (28 acre-feet versus 145 acre-feet). In contrast, the annual runoff for the 1981 water year was greater than the annual runoff for four out of the other six years of record. This illustrated the extreme variability of streamflow within the dry washes, where runoff was derived primarily from isolated intense thunderstorms during the summer. As a result, only limited conclusions concerning annual runoff and peak flow may be drawn at this time from such short duration

streamflow records. The continuation of these monitoring stations will provide more meaningful results at a future time during the project life. The data base should be sufficient to provide critical information during Phase III of the operational period and for the decommissioning period of this project.

No conclusions concerning suspended sediment or water quality are presented since no water samples were collected during the year at the three dry wash monitoring stations.

4.1.2 Bedrock Aquifer

The term bedrck aquifer refers to ground water contained within the Uinta and Green River Formations. The principal aquifers in the project area are the Birds Nest Aquifer (BNA) located in the upper portion of the Parachute Creek Member, and the Douglas Creek Aquifer located in the Douglas Creek Member. Both of these members belong to the Green River Formation. A third bedrock aquifer of limited areal extent is located in a zone near the contact of the lower Uinta and upper Green River Formations, and is referred to as the Upper Aquifer.

4.1.2.1 Objectives

The 1981 work plan involved three major areas of interest regarding bedrock aquifer water. These were: 1) extend the water level data base; 2) provide continuity between earlier baseline conditions and the present monitoring period, and 3) define long-term trends of water levels of the monitored bedrock aquifer wells.

4.1.2.2 Program Design and Methodology

The bedrock aquifer wells used this year were continued from the same group monitored during the baseline program. These wells provide identify water level trends. Table 4.1-11 lists the monitoring wells and their respective aquifers. Figure 4.1-8 shows the location of these wells.

Static water levels were continuously monitored throughout the year by WRSOC at wells P-1, P-2 Upper, P-2 Lower, and P-3. Digital punch recorders recorded the water level every hour at these four wells. For quality control, WRSOC manually checked the water level at all four wells once a month. This consisted of calibrating or resetting the digital recorders monthly based on water levels measured manually using an electric probe.

Semi-annual manual water level readings were taken by WRSOC at G-5, G-8, G-8A, G-10, G-11, G-15, G-21 and P-4 in November 1980 and April 1981, which correspond to maximum and minimum water level periods, respectively, as indicated earlier during the baseline period. All water levels (depth to water) are initially measured from the top of well casings and then corrected to feet below land surface at all deep aquifer monitoring wells.

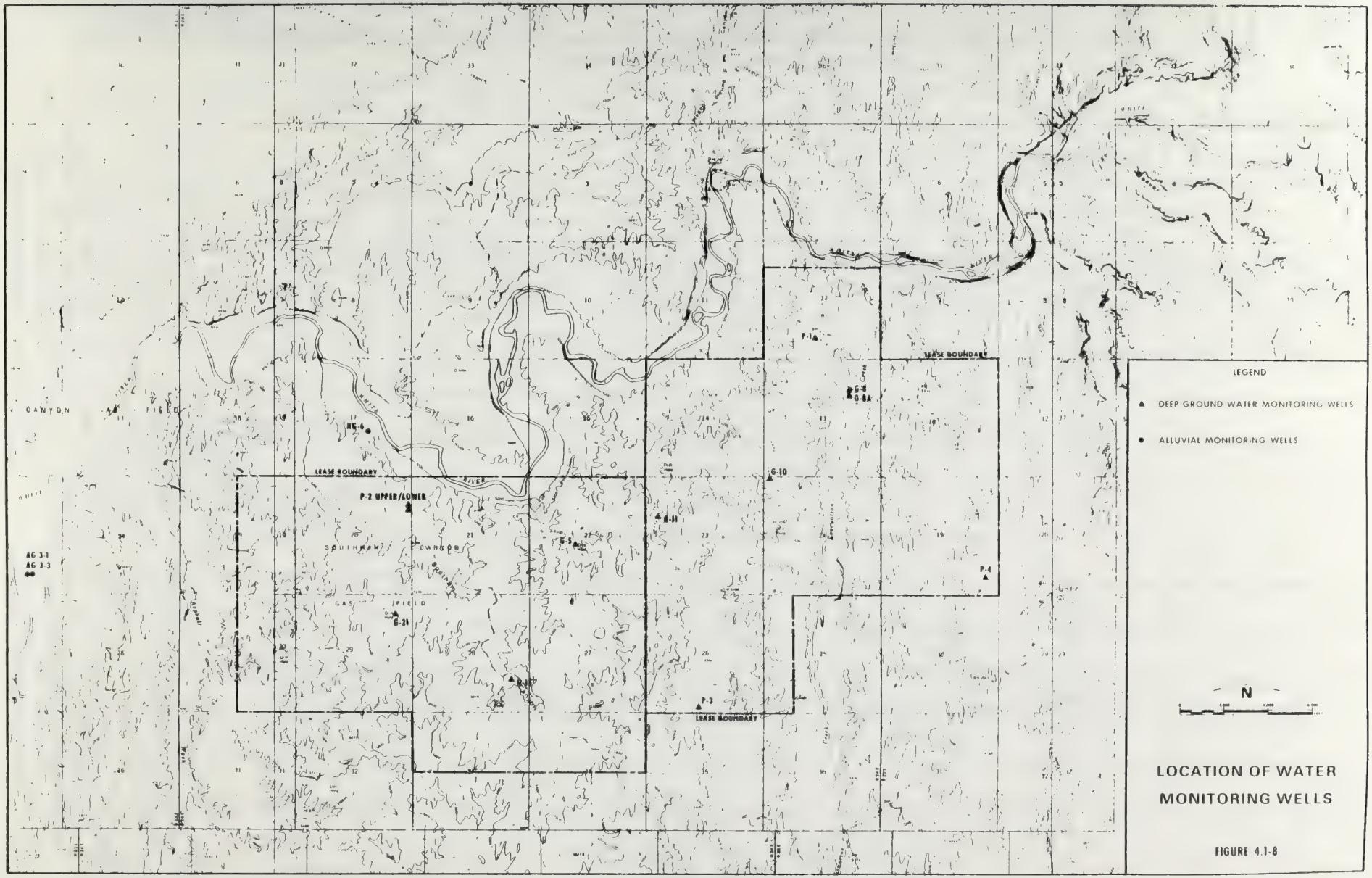
4.1.2.3 Data Summary

The continuous hydrographs for wells P-1, P-2 Upper, P-2 Lower, and P-3 are presented in Figures 4.1-9 and 4.1-10. The data indicated

TABLE 4.1-11

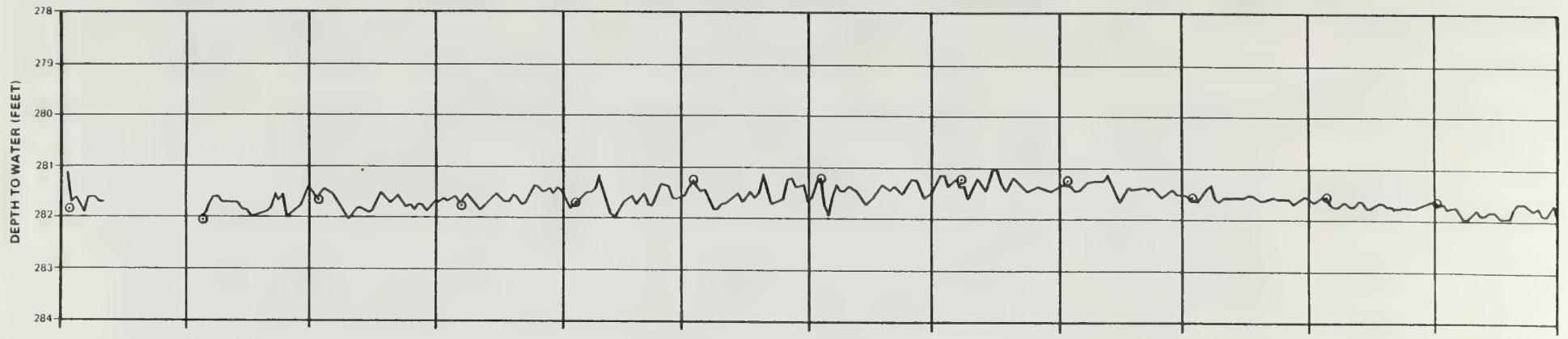
BEDROCK AQUIFER WATER MONITORING WELLS

Well Number	Location	Aquifer Monitored	Water Level Monitoring Frequency
P-1	Evacuation Creek (Section 12)	Birds Nest	Continuous
P-2 Upper	Southam Canyon (Section 20)	Upper	Continuous
P-2 Lower	Southam Canyon (Section 20)	Birds Nest	Continuous
P-3	Evacuation Creek (Section 26)	Birds Nest	Continuous
P-4	Evacuation Creek (Section 19)	Birds Nest and Douglas Creek	Semi-Annual
G-5	Plant Site Wash (Section 22)	Birds Nest	Semi-Annual
G-8	Evacuation Creek (Section 13)	Birds Nest	Semi-Annual
G-8A	Evacuation Creek (Section 13)	Birds Nest	Semi-Annual
G-10	Evacuation Creek (Section 13)	Birds Nest	Semi-Annual
G-11	Plant Site Wash (Section 23)	Birds Nest	Semi-Annual
G-15	Southam Canyon (Section 28)	Birds Nest	Semi-Annual
G-21	Southam Canyon (Section 29)	Birds Nest	Semi-Annual



LOCATION OF WATER MONITORING WELLS

FIGURE 4.1-8

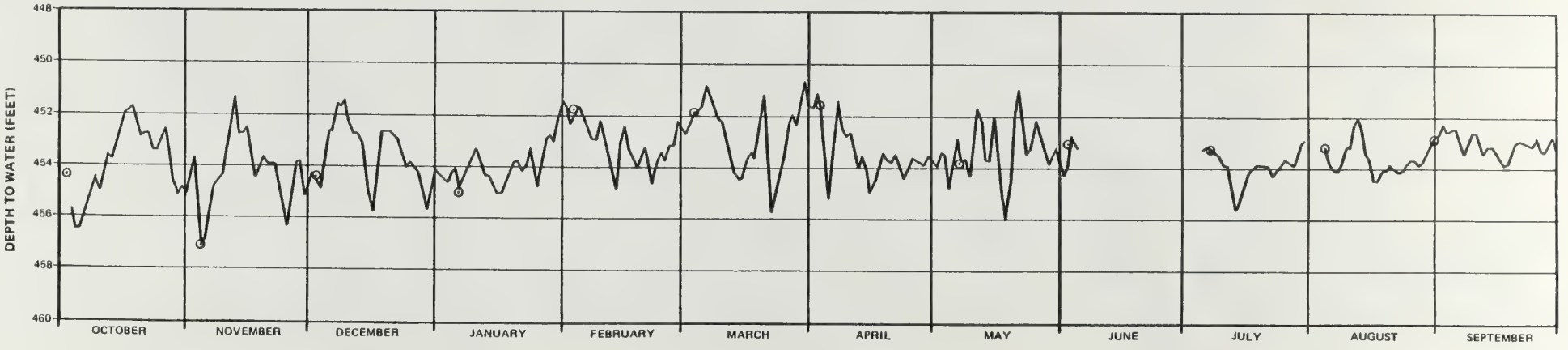


NOTE:
⊙ ARE MANUAL MEASUREMENTS BY ELECTRIC PROBE
ALL MEASUREMENTS FROM APPROXIMATE TOP OF COLLAR
LAND SURFACE ELEVATION = 5284.0
WELL COLLAR ELEVATION = 5286.9

CONTINUOUS STATIC WATER LEVEL MEASUREMENTS

MONITOR WELL P-1

OCTOBER 1980 – SEPTEMBER 1981



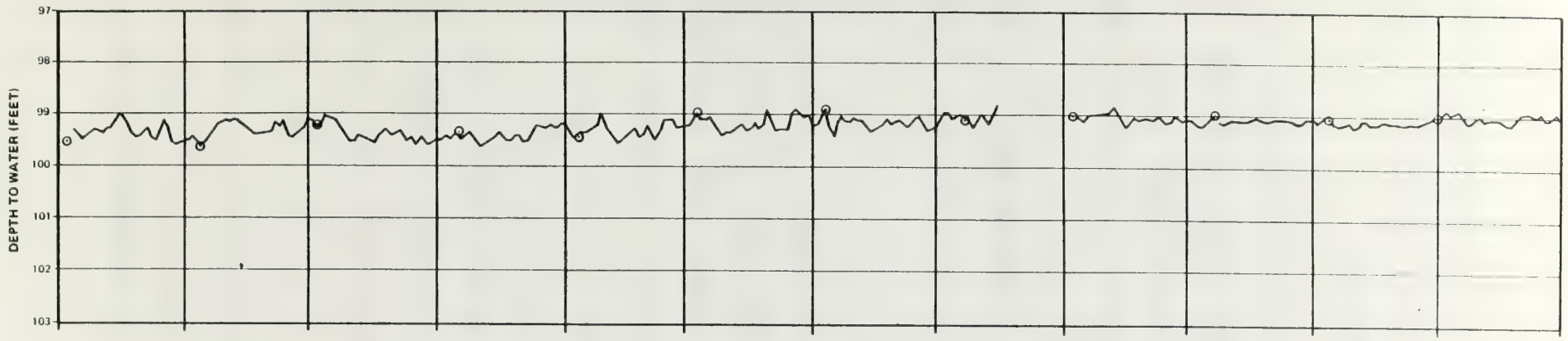
NOTE:
⊙ ARE MANUAL MEASUREMENTS BY ELECTRIC PROBE
ALL MEASUREMENTS FROM APPROXIMATE TOP OF COLLAR
LAND SURFACE ELEVATION = 5486.0
WELL COLLAR ELEVATION = 5489.0

CONTINUOUS STATIC WATER LEVEL MEASUREMENTS

MONITOR WELL P-3

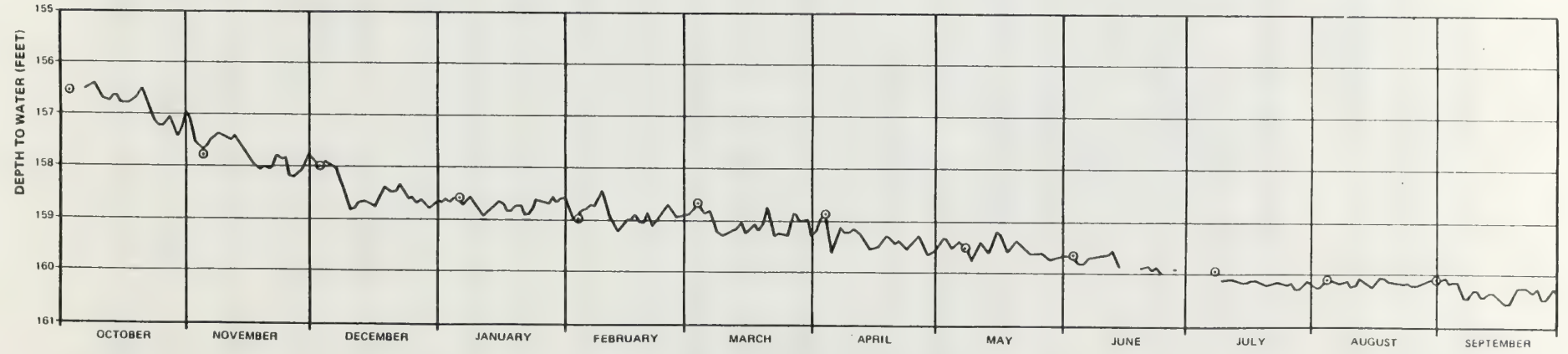
OCTOBER 1980 – SEPTEMBER 1981

FIGURE 4.1-9



NOTE:
⊙ ARE MANUAL MEASUREMENTS BY ELECTRIC PROBE
ALL MEASUREMENTS FROM APPROXIMATE TOP OF COLLAR
LAND SURFACE ELEVATION = 4991.0
WELL COLLAR ELEVATION = 4994.5

CONTINUOUS STATIC WATER LEVEL MEASUREMENTS
MONITOR WELL P-2 UPPER
OCTOBER 1980 – SEPTEMBER 1981



NOTE:
⊙ ARE MANUAL MEASUREMENTS BY ELECTRIC PROBE
ALL MEASUREMENTS FROM APPROXIMATE TOP OF COLLAR
LAND SURFACE ELEVATION = 4990.5
WELL COLLAR ELEVATION = 4993.3

CONTINUOUS STATIC WATER LEVEL MEASUREMENTS
MONITOR WELL P-2 LOWER
OCTOBER 1980 – SEPTEMBER 1981

FIGURE 4.1.10

that the mean static water levels of wells P-1, P-2 Upper and P-3 have remained steady throughout the year. Maximum fluctuations of 1.0 foot were characteristic of wells P-1 and P-2 Upper.

The 1981 annual mean water level of well P-3 was similar to the mean for the 1980 water year. An annual variation of 6.7 feet was recorded during the 1981 water year. This pattern of static water level fluctuation was very similar to that observed in water year 1980. Table 4.1-12 shows a comparison of 1980 versus 1981 water levels at P-3. Overall water levels at P-3 rose about 41 feet by 1979 from the 1976 baseline levels. This trend toward rising water level has leveled off over the last two years.

Water level at well P-2 Lower has declined steadily throughout the 1981 water year by about four feet. Approximately two feet of net water level decline occurred during October-December 1980. Depth to water during the water year ranged from 156.6 feet to 160.8 feet below well collar, for an annual fluctuation of about 4.2 feet. Water levels were lowest during September 1981. Static water levels at P-2 Lower are currently a foot or two below average baseline elevations, and are lower than at any time during the period of record. This is a continuation of a slow trend toward declining water levels that has occurred since mid-1980.

Water levels were measured semi-annually at wells G-5, G-8, G-8A, G-10, G-11, G-15, G-21 and P-4 as shown in Table 4.1-13. A comparison was made of 1981 semi-annual static water level measurements at these

TABLE 4.1-12

STATIC WATER LEVEL COMPARISON
1980-1981 WATER YEARS*

Monitoring Well P-3--Birds Nest Aquifer

Year	Maximum	Minimum	Range	Mean Depth
1980	447.0	452.9	5.9	450.8
1981	447.3	454.0	6.7	450.5

* All values are depth to water in feet below ground surface.

TABLE 4.1-13

SEMI-ANNUAL WATER LEVEL MEASUREMENTS
BEDROCK AQUIFER WATER WELLS
1981 WATER YEAR

Well Number	Total Well Depth (feet)	Approx. Ground Surface Elevation (feet)	Static Water Level		
			Depth Below Ground Surface (feet)	Approx. Elevation (feet)	Date Measured
G-5	620	5,292.0	456.9	4,835.1	11/5/80
			458.9	4,833.1	4/29/81
G-8	127	5,095.5	50.7	5,044.8	11/5/80
			50.1	5,045.4	4/29/81
G-8A	100	5,095.0	38.7	5,056.3	11/5/80
			37.2	5,057.8	4/29/81
G-10	400	5,364.0	312.5	5,051.5	11/5/80
			304.0	5,060.0	4/29/81
G-11	650	5,375.0	463.9	4,911.1	11/5/80
			463.9	4,911.1	4/29/81
G-15	627	5,343.0	506.7	4,836.3	11/5/80
			508.7	4,834.3	4/29/81
G-21	611	5,262.0	427.0	4,835.0	11/5/80
			428.7	4,833.3	4/29/81
P-4	400	5,718.5	262.3	5,456.2	11/5/80
			262.4	5,456.1	4/29/81

wells with similar data from the past several years to identify recent water level trends at these wells. Table 4.1-14 shows water level measurements taken at these wells from 1978 through the current (1981) water year. In general, annual static water level fluctuations and mean water levels at these wells have remained within historic ranges through 1981. Recently, there has been a slight decline in water levels at wells G-5, G-15, and G-21.

4.1.2.4 Conclusions

The continuous water levels of the bedrock aquifer monitoring wells during the 1981 water year have maintained levels similar to those found during the baseline period in all three bedrock aquifers (Upper, Birds Nest and Douglas Creek) with the exception of wells P-2 Lower and P-3, G-5, G-15 and G-21.

The observed decline in static water levels (four feet) at well P-2 Lower was not considered a significant or permanent depletion of storage in the Birds Nest Aquifer (BNA). Although this trend was not apparent in all wells monitoring the BNA, a review of the last several years' record indicated a recent slight decline in static water levels from the 1980 to 1981 water years at G-5, G-15 and G-21. These are the nearest BNA wells to P-2 Lower and are also located in Tract Ua. Although of lesser magnitude, the decline in static water levels at these wells (monitored semi-annually rather than continuously) may be related to the decline observed at P-2 Lower. The other BNA wells (located in Tract Ub) have remained essentially stable over the same

TABLE 4.1-14

SUMMARY OF SEMI-ANNUAL WATER LEVEL MEASUREMENTS
BEDROCK AQUIFER WATER WELLS (BY WATER YEAR)
DEPTH TO WATER (FEET BELOW GROUND SURFACE)

Well	Water Year 1978	Date	Water Year 1979	Date	Water Year 1980	Date	Water Year 1981	Date
G-5	456.6	11/7/77	456.7	11/14/78	454.8	11/20/79	456.9	11/5/80
	456.6	4/13/78	455.6	4/23/79	455.1	4/21/80	458.9	4/29/81
G-8	50.7	11/7/77	51.0	11/14/78	50.6	11/19/79	50.7	11/5/80
	50.3	4/13/78	50.0	4/23/79	49.7	4/21/80	50.1	4/29/81
G-8A	39.7	11/7/77	39.5	11/14/78	45.2	11/19/79	38.7	11/5/80
	38.5	4/13/78	38.7	4/23/79	38.7	4/21/80	37.2	4/29/81
G-10	315.5	11/7/77	314.2	11/14/78	313.0	11/20/79	312.5	11/5/80
	308.6	4/13/78	305.8	4/23/79	305.7	4/21/80	304.0	4/29/81
G-11	466.2	11/7/77	466.9	11/14/78	462.6	11/20/79	463.9	11/5/80
	466.1	4/13/78	465.3	4/23/79	463.9	4/21/80	463.9	4/29/81
G-15	505.9	11/7/77	506.2	11/14/78	504.3	11/20/79	506.7	11/5/80
	505.9	4/13.78	504.7	4/23/79	504.8	4/21/80	508.7	4/29/81
G-21	426.8	11/7/77	426.8	11/14/78	426.7	11/20/79	427.0	11/5/80
	426.6	4/13/78	423.9	4/23/79	425.1	4/21/80	428.7	4/29/81
P-4	263.0	11/7/77	263.2	11/14/78	262.8	11/19/79	262.3	11/5/80
	262.7	4/13/78	262.7	4/23/79	262.0	4/21/80	262.4	4/29/81

period. The different responses in static water levels observed between the two areas are probably related to one or a combination of the following general factors:

- o Diminished local natural recharge to the BNA.
- o Increased local man-made discharge (pumping) from the BNA.
- o High response sensitivity of the static water level to changes in recharge/discharge events due to greater transmissivity in the BNA at P-2 Lower relative to BNA transmissivity in other parts of the project area.

There is no direct evidence supporting a conclusion regarding any of the above causes. The range of fluctuation is still within ranges observed at other BNA wells. If the static water levels continue to decline throughout the 1982 water year, then a more detailed analysis of possible causes may be appropriate.

Static water levels in P-3 have apparently stabilized as evidenced from previously recorded data. This conclusion was reached in 1980 and is confirmed by 1981 monitoring. During May 1979, P-3 reached a maximum level of 443.7 feet and then declined to levels between 449.0 feet and 453.0 feet below land surface. However, during 1980 and 1981 monitoring, no substantial rise or decline in the water level of P-3 was observed. The mechanisms which caused the fluctuations and overall decline in static water levels in well P-3 may be attributed to various phenomena (barometric efficiency, H_2S gas emissions). None of these

phenomena have, as yet, been studied in sufficient detail to enable an accurate assessment of the effects of the mechanisms involved.

Static water levels and fluctuations during 1981 at wells P-1, P-2 Upper, G-8, G-8A, G-10, G-11, and P-4 were within normally expected ranges compared with previous monitoring years.

4.1.3 Alluvial Ground Water

The alluvial aquifer program involved a continuation of the 1980 monitoring program for ground water contained in the alluvium at the mouth of Southam Canyon and in the White River alluvium downstream of the tracts.

4.1.3.1 Objectives

The 1981 work plan involved three major areas of interest: 1) extension of the data base in regard to water levels and field measurements of water quality; 2) provide continuity between baseline conditions and the present monitoring period, and 3) define long-term trends of water level and water quality of the monitored alluvial wells.

4.1.3.2 Program Design and Methodology

The program involved monitoring alluvial wells AG-3-1 (Lower), AG-3-3 (Upper) and AG-6-1 (Lower). Table 4.1-15 lists the alluvial monitoring wells and their respective aquifers. Figure 4.1-8 shows the locations of the alluvial ground water monitoring wells. Program efforts involved measuring static water levels, temperature, pH and specific conductance during the months of September 1980 and April 1981.

TABLE 4.1-15

ALLUVIAL MONITORING WELLS

Well Number	Location	Aquifer Monitored	Water Level Monitoring Frequency
AG-3-1	White River, 2 miles east of Tract U-a (Section 23)	White River alluvium	Semi-Annual
AG-3-3	Same as AG-3-1	White River alluvium	Semi-Annual
AG-6-1	Southam Canyon (Section 17)	Southam Canyon alluvium	Semi-Annual

The September 1980 measurements were actually taken one day to one week before the 1981 water year began, and are reported here and in the 1980 Progress Report. The measurements for these wells were not expected to change materially by the beginning of the 1981 water year (October 1980), and are considered representative of early 1981 water year conditions. A new set of measurements in October 1980 was therefore considered to be unnecessary. Alluvial well field data collection is planned for October and April during the 1982 water year.

4.1.3.3 Data Summary

Static Water Levels

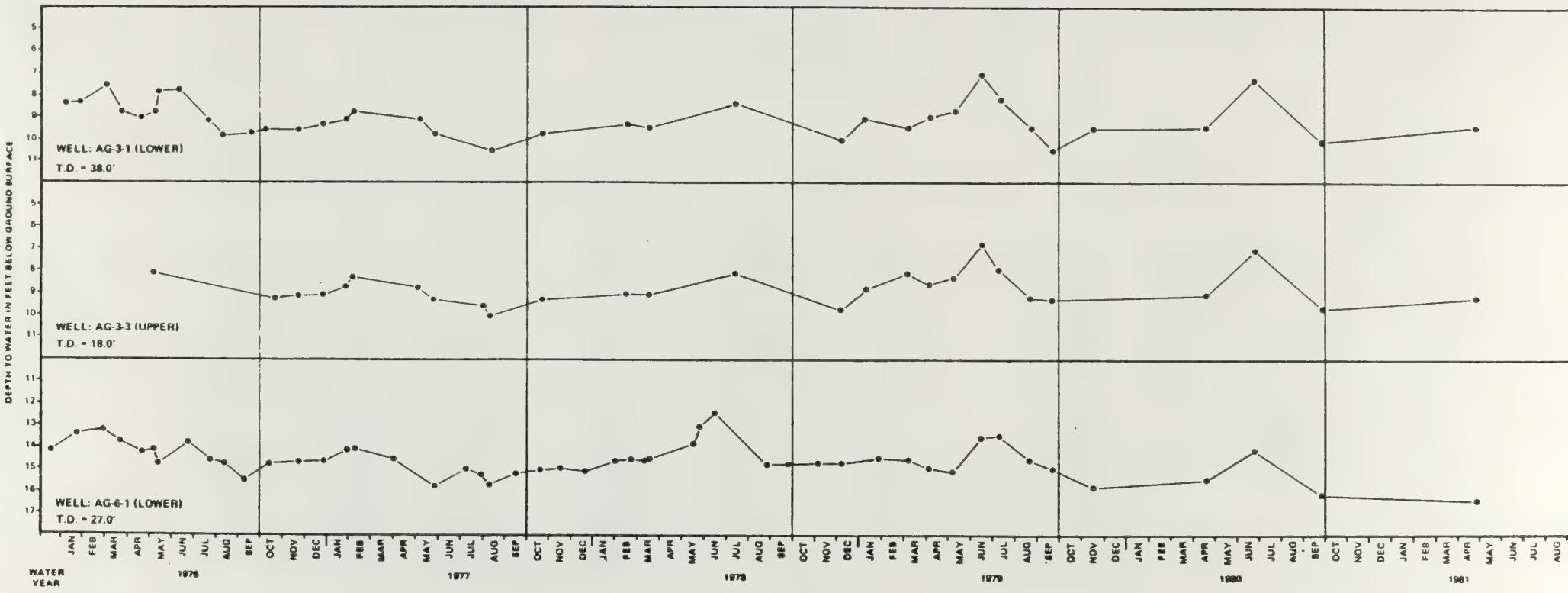
The measurements of the static water level of the three alluvial wells are presented in Table 4.1-16. The depth of the static water level was measured from the top of the well casing and then corrected for the length of casing above the ground to depth below land surface. Long-term hydrographs depicting water level changes in the three alluvial wells over the entire period of record are shown on Figure 4.1-11.

Alluvial well AG-3-1 in the White River alluvium exhibited a water level fluctuation of 0.6 feet with the higher water level recorded in April 1981. Water levels at well AG-3-3 were approximately the same in April 1981 and September 1980. A review of the pre-1981 record of AG-3-1 and AG-3-3 indicated highest static water levels have occurred during the period of June-July while the lowest levels have occurred generally during the periods between September and November. The maximum water level fluctuation for AG-3-1 and AG-3-3 for the entire

TABLE 4.1-16

MONITORING WELL MEASUREMENTS
ALLUVIAL GROUND WATER WELLS
1981 WATER YEAR

Well Number	Total Well Depth (feet)	Static Water Level: Approx. Ground Surface Elevation (feet)	Static Water Level: Depth Below Ground Surface (feet)	Approx. Elevation (feet)	Water Temperature (°C)	Specific Conductance (umhos/cm)	pH	Date Measured
AG-3-1	38.0	4,860.0	10.2	4,849.8	13.8	3,300	7.2	9/30/80
			9.6	4,850.4	9.8	2,900	7.5	4/29/81
AG-3-3	18.0	4,860.0	9.8	4,850.2	14.2	2,820	7.4	9/30/80
			9.8	4,850.2	10.2	1,800	8.0	4/29/81
AG-6-1	27.0	4,960.0	16.2	4,943.8	13.8	1,300	8.0	9/25/80
			16.6	4,943.4	13.5	1,200	8.0	4/29/81



LEGEND

T.D. DENOTES TOTAL WELL DEPTH BELOW GROUND SURFACE

MEASURED STATIC WATER LEVELS IN ALLUVIAL WELLS

DECEMBER 1975 – SEPTEMBER 1981

BY WATER YEAR

FIGURE 4.1-11

period of record was 3.45 feet and 3.37 feet, respectively. The 1981 annual fluctuation and mean water level of the wells remained within historic ranges at AG-3-1 and AG-3-3.

Alluvial well AG-6-1 in Southam Canyon alluvium exhibited a water level fluctuation of 0.4 feet during the year, with the higher static water level occurring in April 1981. Inspection of the pre-1981 water level record of AG-6-1 indicated that highest static water levels have occurred in the period May-June while the lowest have occurred generally between August-October. The maximum water level fluctuation for the entire period of record through the 1981 water year was about 3.65 feet.

Water Quality

The 1981 field measurements of temperature, pH and specific conductance for these alluvial wells are presented in Table 4.1-16. At well AG-3-1, temperature values ranged from a low of 9.8°C in the month of April 1981 to a high of 13.8°C during September 1980. pH ranged from 7.5 in April to 7.2 in September . Specific conductance values ranged from 2900 umhos/cm in April to 3300 umhos/cm in September. Inspection of the entire record of specific conductance for AG-3-1 indicated a range from a low of 3,200 umhos/cm to a high of 4,600 umhos/cm.. At well AG-3-3, the water temperature values ranged from a low of 10.2°C in April to a high of 14.2°C in September. pH ranged from 8.0 in April to 7.4 in September. Specific conductance values ranged from a new low of 1,800 umhos/cm in April to a high of 2,820 umhos/cm in September. Inspection of the pre-1981 record of specific

conductance for AG-3-3 indicated a previous range of 2,800 umhos/cm to 4,200 umhos/cm. The new record 1981 low of 1,800 umhos/cm extended the range of specific conductance monitored at AG-3-3 from the prevous 2,800-4,200 umhos/cm to 1,800-4,200 umhos/cm.

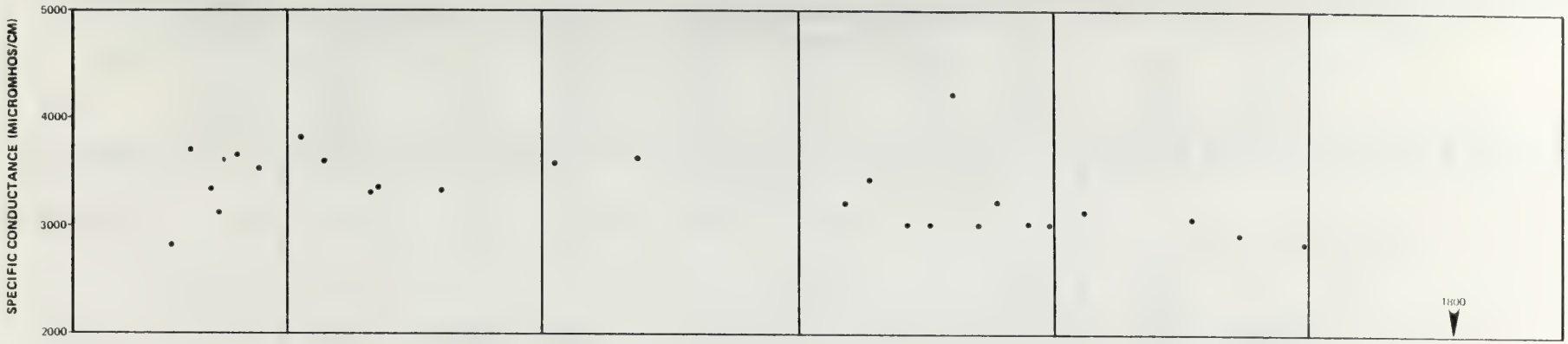
Alluvial well AG-6-1 in Southam Canyon showed a temperature range between 13.5°C and 13.8°C. pH was 8.0 on both sampling dates. Specific conductance values ranged from a low of 1,200 umhos/cm in April 1981 to a high of 1,300 umhos/cm in September 1980. Inspection of the entire record of specific conductance for AG-6-1 indicated a low of 1,225 umhos/cm to a high of 7,250 umhos/cm.

Conductivity measurements for the three alluvial wells during the entire period of record are shown in Figures 4.1-12 and 4.1-13.

The specific conductance value for well AG-3-3 during April 1981 was well below previously recorded values. Therefore, a water quality sample was collected and analyzed. Results of the analysis are shown in Table 4.1-17.

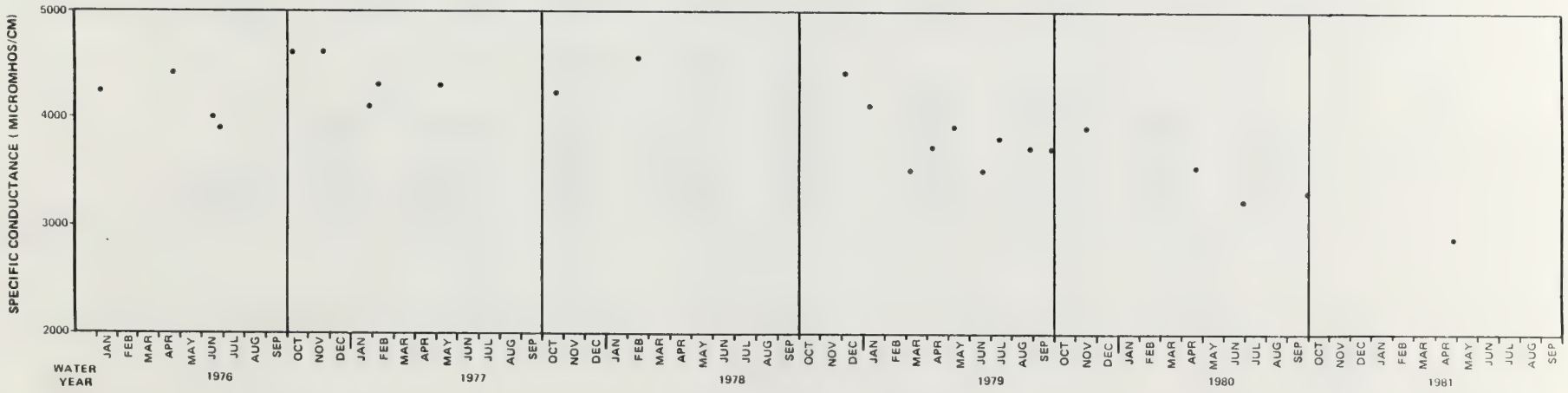
This year's water quality analysis for well AG-3-3 was compared with previous baseline and interim montoring analyses in order to identify trends in water quality recorded at ths well. No major changes in overall water quality have occurred over the period of record, but the following trends were observed as a result of the comparison:

- Most major ions have declined slightly over time.



LEGEND
• SPECIFIC CONDUCTANCE MEASUREMENT

ALLUVIAL WELL AG-3-3 (UPPER)
APRIL 1976 – SEPTEMBER 1981

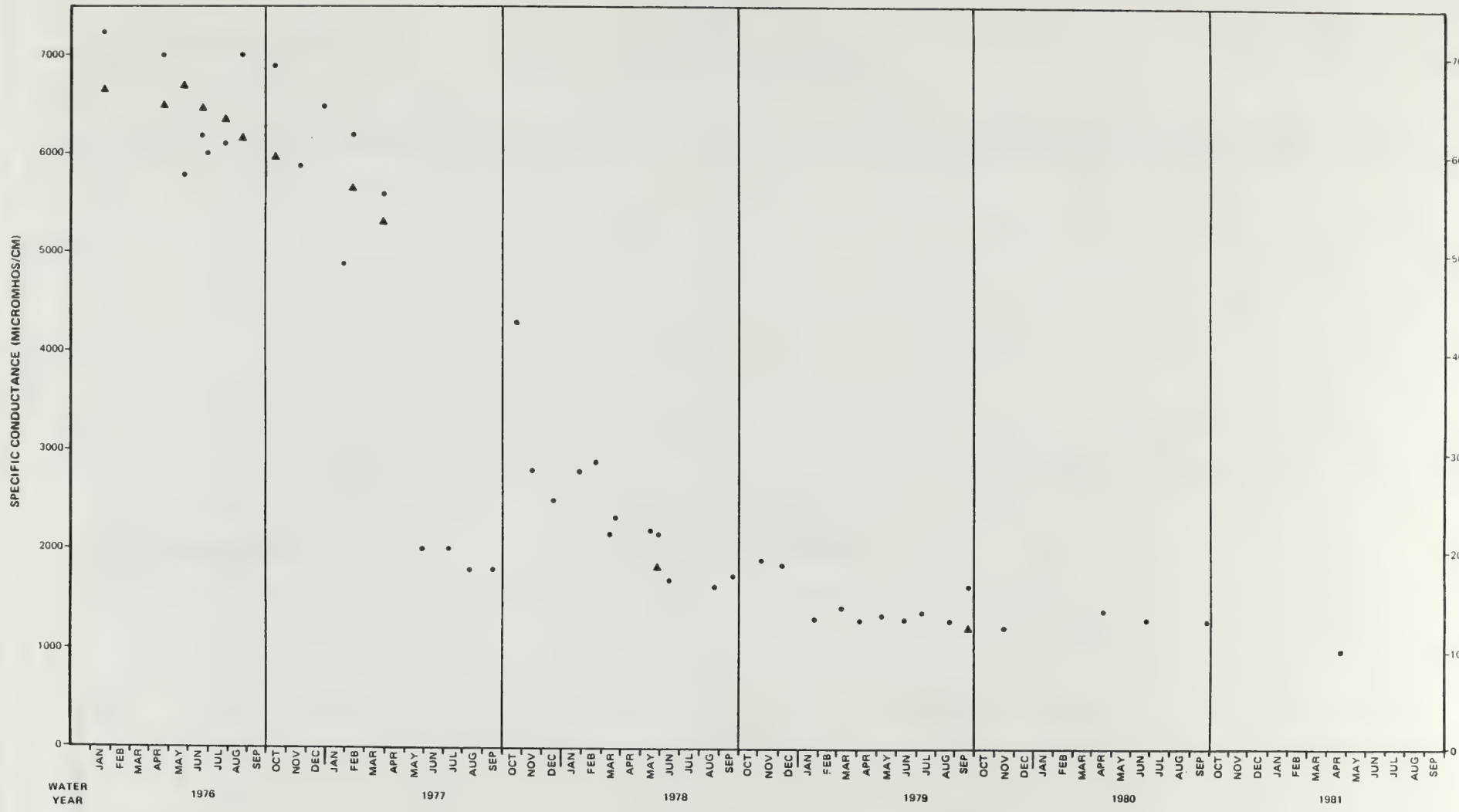


LEGEND
• SPECIFIC CONDUCTANCE MEASUREMENT

ALLUVIAL WELL AG-3-1 (LOWER)
JANUARY 1976 – SEPTEMBER 1981

SPECIFIC CONDUCTANCE
BY WATER YEAR

FIGURE 4.1-12


SPECIFIC CONDUCTANCE (MICROMHOS/CM)
0
1000
2000
3000
4000
5000
6000
7000
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
WATER YEAR
1976
1977
1978
1979
1980
1981
LEGEND
SPECIFIC CONDUCTANCE
TOTAL DISSOLVED SOLIDS

ALLUVIAL WELL AG-6-1
JANUARY 1976 – SEPTEMBER 1981

SPECIFIC CONDUCTANCE AND TOTAL DISSOLVED SOLIDS
BY WATER YEAR

FIGURE 4.1-13

TABLE 4.1-17. WELL ID 395554109172703 - AG-3-3 WHITE RIVER ALLUVIUM
WATER QUALITY DATA, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	WATER LEVEL (FEET BELOW LSD)	WATER TEMPER-ATURE (DEG C)	PH FIELD (UNITS)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	SPECI-FIC CONDUC-TANCE LAB, UMHS@25	TOTAL DISS SOLIDS (SUM) (MG/L)	CALCIUM DISS (MG/L)	MAGNE-SIUM DISS (MG/L)	SODIUM DISS (MG/L)	POTAS-SIUM DISS (MG/L)
06/18/81	0945	9.50	12.1	7.4	1820	1900	1290	63	50	310	2.5

DATE	TIME	ALKALI-NITY, LAB (MG/L AS CACO3)	SUL-FATE DISS (MG/L)	CHLOR-IDE DISS (MG/L)	FLUOR-IDE DISS (MG/L)	SILICA DISS (MG/L)	SULFIDE TOTAL (MG/L)	BROMIDE DISS (MG/L)	HARD-NESS TOTAL (AS CACO3) (MG/L)	HARD-NESS, NONCAR. (AS CACO3) (MG/L)	SODIUM ADSORP RATIO (SAR)
06/18/81	0945	390	550	62	0.6	17	0,0	0.10	360	0	7.1

DATE	TIME	PERCENT SODIUM	AMMONIA DISS (AS N) (MG/L)	AMMONIA DISS AS NH4 (MG/L)	AMMONIA + ORG NITRO TOTAL (AS N) (MG/L)	NITRITE PLUS NITRATE DISS (AS N) (MG/L)	PHOS-PHATE TOTAL (MG/L AS PO4)	PHOS-PHORUS, TOTAL (AS P) (MG/L)	PHOS-PHORUS, ORTHO DISS (AS P) (MG/L)	OXYGEN DEMAND CHEM (MG/L)	ORGANIC CARBON DISS (MG/L)
06/18/81	0945	65	0.010	0.01	2.6	0.00	2.1	0.690	0.000	71	13

TABLE 4.1-17 (CONTINUED). WELL ID 395534109172703 - AG-3-3 WHITE RIVER ALLUVIUM
WATER QUALITY DATA: WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

DATE	TIME	ALUMINUM DISS (UG/L)	ARSENIC DISS (UG/L)	BARIUM DISS (UG/L)	BORON DISS (UG/L)	CADMIUM DISS (UG/L)	CHROMIUM DISS (UG/L)	COPPER DISS (UG/L)	IRON DISS (UG/L)	LEAD DISS (UG/L)	LITHIUM DISS (UG/L)
06/18/81	0945	0	4	100	3200	<1	10	17	40	3	70

DATE	TIME	MANGANESE DISS (UG/L)	MERCURY DISS (UG/L)	MOLYBDENUM DISS (UG/L)	SELENIUM DISS (UG/L)	STRONTIUM DISS (UG/L)	VANADIUM DISS (UG/L)	ZINC DISS (UG/L)	PHENOLS (UG/L)	POTASSIUM 40 DISS (PCI/L)
06/18/81	0945	150	0.0	49	0	1000	0.00	30	1	1.9

- o Trace element and nutrients concentrations have generally remained steady or declined very slightly.

- o Several trace metal concentrations have increased by very minor amounts above initial baseline levels.

4.1.3.4 Conclusions

The results of the alluvial aquifer monitoring program differed little from those collected in previous years. Water levels in well AG-3-1 were relatively stable and displayed little change since the begining of monitoring. Field water quality data indicated no significant variation in water quality during 1981.

Static ground water levels and temperatures at AG-3-3 were unchanged from previous years. Specific conductance dropped below the previous low of 2,800 umhos/cm to 1,800 umhos/cm. This change in specific conductance represented a slight improvement in overall water quality at this well.

Mean water level and temperatures at well AG-6-1 in Southam Canyon have remained stable over the entire period of record. However, specific conductance values have changed significantly since the start of baseline monitoring. Current values range between 1,000 and 2,000 umhos/cm from a first year range of between 6,000 and 7,000 umhos/cm. Because specific conductance values have ranged between 1,000 and 2,000 umhos/cm since 1978 it is felt that well AG-6-1 has stabilized.

4.1.4 Precipitation/Evaporation

The precipitation/evaporation aspect of the 1981 water resources monitoring program included data collected through the combined efforts of the White River Shale Oil Corporation (WRSOC) and the Bureau of Land Management (BLM). During the 1981 water year, WRSOC continued pre-development monitoring with a site-specific network of precipitation gauges and evaporation pans located on, or in proximity to, the tracts. These data have been combined with data collected by a BLM regional network of precipitation gauges distributed throughout the southeast Uinta Basin in the vicinity of the tracts.

4.1.4.1 Objectives

The objectives of WRSOC's 1981 precipitation/evaporation monitoring program were: 1) to provide site-specific information on precipitation and evaporation at both the plant site and the processed shale disposal area; 2) to continue efforts to establish the seasonal and annual precipitation patterns on the tracts; 3) to augment the BLM regional data collection network; 4) to study the probable path of summer thunderstorms across the tracts, and 5) to investigate the reliability of the U.S. Weather Bureau 24-hour duration, 100-year design storm value of 2.4 inches.

4.1.4.2 Program Design and Methodology

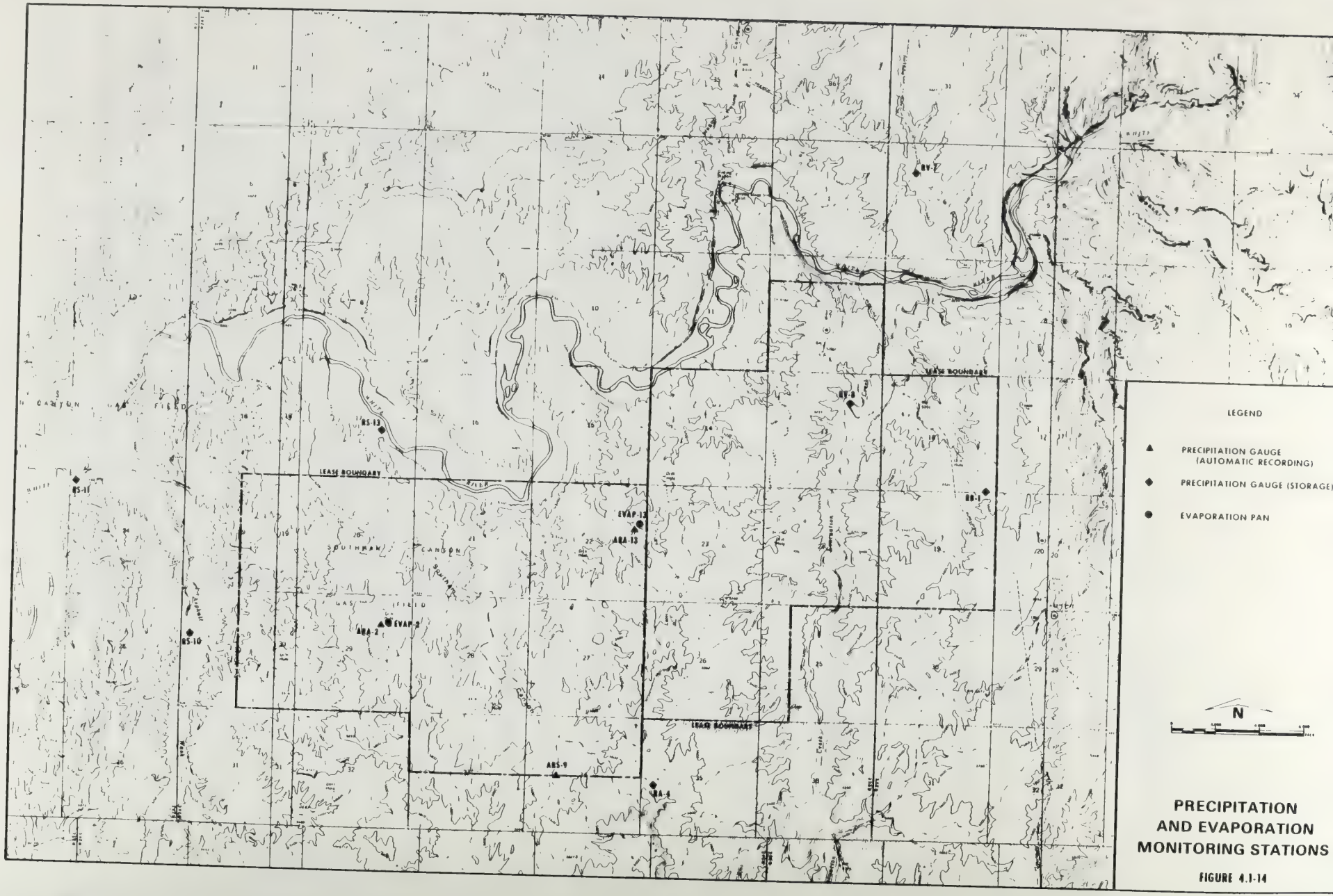
The precipitation/evaporation program was designed to provide support data for the hydrologic, meteorologic, biologic and engineering tasks associated with the White River Shale Project.

Precipitation

Precipitation (water equivalent) was monitored at ten locations on or near the tracts. The current location of the gauges are shown on Figure 4.1-14. The specific equipment at each site (i.e. gauge type) is listed in Table 4.1-18. Station designations beginning with the letter "A" were of an automatic recording type. Recording gauges were operated during October 1980 and from April through September 1981 at two locations in Southam Canyon (ARA-2 and ARS-9). A third recording gauge was operated year round (October 1980-September 1981) at the plant site (ARA-13).

Recording gauges were of the Fischer-Porter type which mechanically converted the depth of accumulated precipitation over a period of time to a code disk position. This code disk position is then recorded on a punched paper tape at selected intervals. The measurement device consisted of a collection bucket, a weighing device and an indicating dial to display accumulated precipitation. A recording mechanism operated with the measuring device to record, on paper tape to the nearest 0.1 inch, the precipitation accumulated in a predetermined interval. Visual readings can be made as well.

Stations with designations beginning with the letter "R" were standard storage gauges. The remaining seven gauges in the network were of this type and located at the following locations: 1) the mouth of Southam Canyon (RS-13); 2) at the revegetation study plot in Section 6, north of the White River (RV-7); 3) at the revegetation study plot



PRECIPITATION AND EVAPORATION MONITORING STATIONS

FIGURE 4.1-14

TABLE 4.1-18

PRECIPITATION AND EVAPORATION MONITORING GAUGES

Station Designation	Type of Gauge	Monitoring Period
Precipitation		
ARA-13	Recording	Year round
ARA-2	Recording	April through October
ARS-9	Recording	April through October
RA-4	Storage	Year round
RB-1	Storage	Year round
RS-10	Storage	Year round
RS-11	Storage	Year round
RS-13	Storage	Year round
RV-7	Storage	Year round
RV-8	Storage	Year round
Evaporation		
EVP-2	Pan	April through October
EVP-13	Pan	April through October

in the Evacuation Creek drainage (RV-8); 4) on the ridge between the Southam Canyon and Evacuation Creek drainage at Air Station A-4 (RA-4); 5) along the White River near the mouth of Asphalt Wash (RS-11); 6) in the Asphalt Wash drainage near vegetation plot VG-3 (RS-10), and 7) in the Evacuation Creek drainage near vegetation plots VS-1 and VS-2 (RB-1).

Evaporation

Measurements of evaporation were made in Southam Canyon (EVP-2) and at the plant site (EVP-13) during the freeze-free period between May 8 and October 16, 1981. Figure 4.1-14 and Table 4.1-18 noted above, also contain locations and equipment for the evaporation sites.

Screened pans were used to measure evaporation. The screens were placed over the pans to prevent wildlife from consuming the water. One pan was located on an exposed ridge in Southam Canyon and a second in a somewhat protected valley at the plant site. The need for multiple locations resulted from the effects of terrain and air flow on evaporation rates. The established network was used to define characteristic terrain effects occurring on the tracts.

4.1.4.3 Data Summary

The following section summarizes the precipitation and evaporation data collected and analyzed for the 1981 water year. The raw data on which the analysis was performed can be found in the 1981 Field Data Report, along with an explanation of the estimation techniques used.

Precipitation

Monthly, seasonal and annual precipitation for the 1981 monitoring network are presented in Table 4.1-19. Isohyetal analysis of seasonal and annual precipitation for the tracts are presented in Figures 4.1-15 through 4.1-19. The data collected by the BLM during 1981, presented as annual totals, are shown in Figure 4.1-20.

Annual precipitation at the WRSOC gauges ranged from a high at RA-4 of 9.27 inches to a low of 6.32 inches at RS-10. The 1981 tract average (Geometric Mean), based on 10 gauges was 8.03 inches.

Precipitation at the plant site for 1981 totalled 7.40 inches. Precipitation was recorded on 43 days with the greatest daily (24-hour) and single event occurring on May 3 and 4, 1981, when a total of 0.90 inches fell over a 15-hour period. While the timing varied between sites, ARA-2 also recorded 0.90 inches during the same period.

On a seasonal basis, spring (April-June) recorded the largest portion of the annual total followed by summer, fall and winter in descending order. Precipitation totals for these periods were 2.67, 2.48, 1.60 and 1.38 inches respectively. The largest variability in precipitation between gauges was observed during spring due to thunderstorm activity.

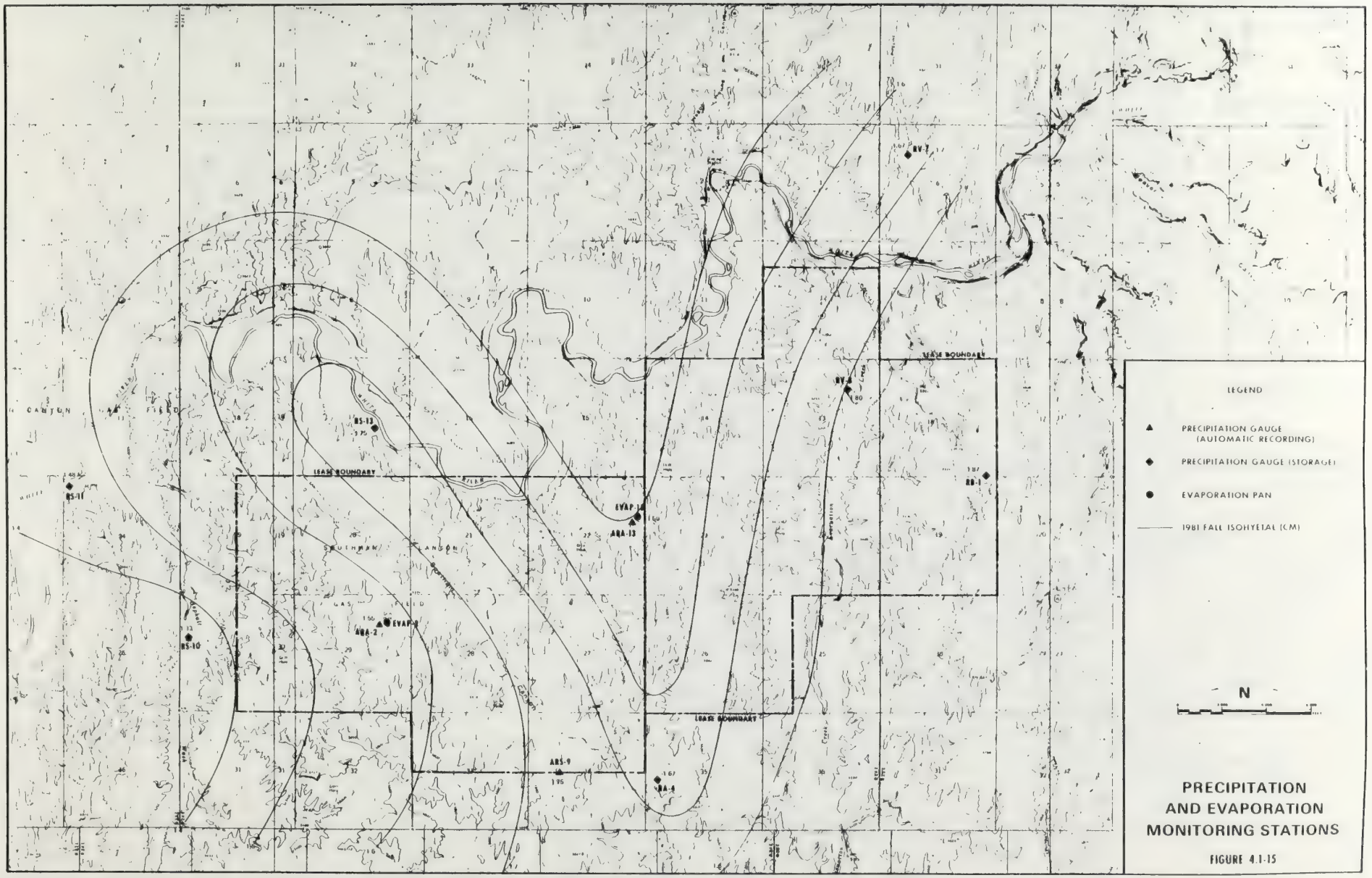
The patterns noted in previous years for the BLM Regional network of gauges have continued. Annual totals ranged from a low of 5.5 inches at Cottonwood, 22 miles southwest of the tracts, to a high of 17.4 inches at South Canyon, 30 miles south of the tracts.

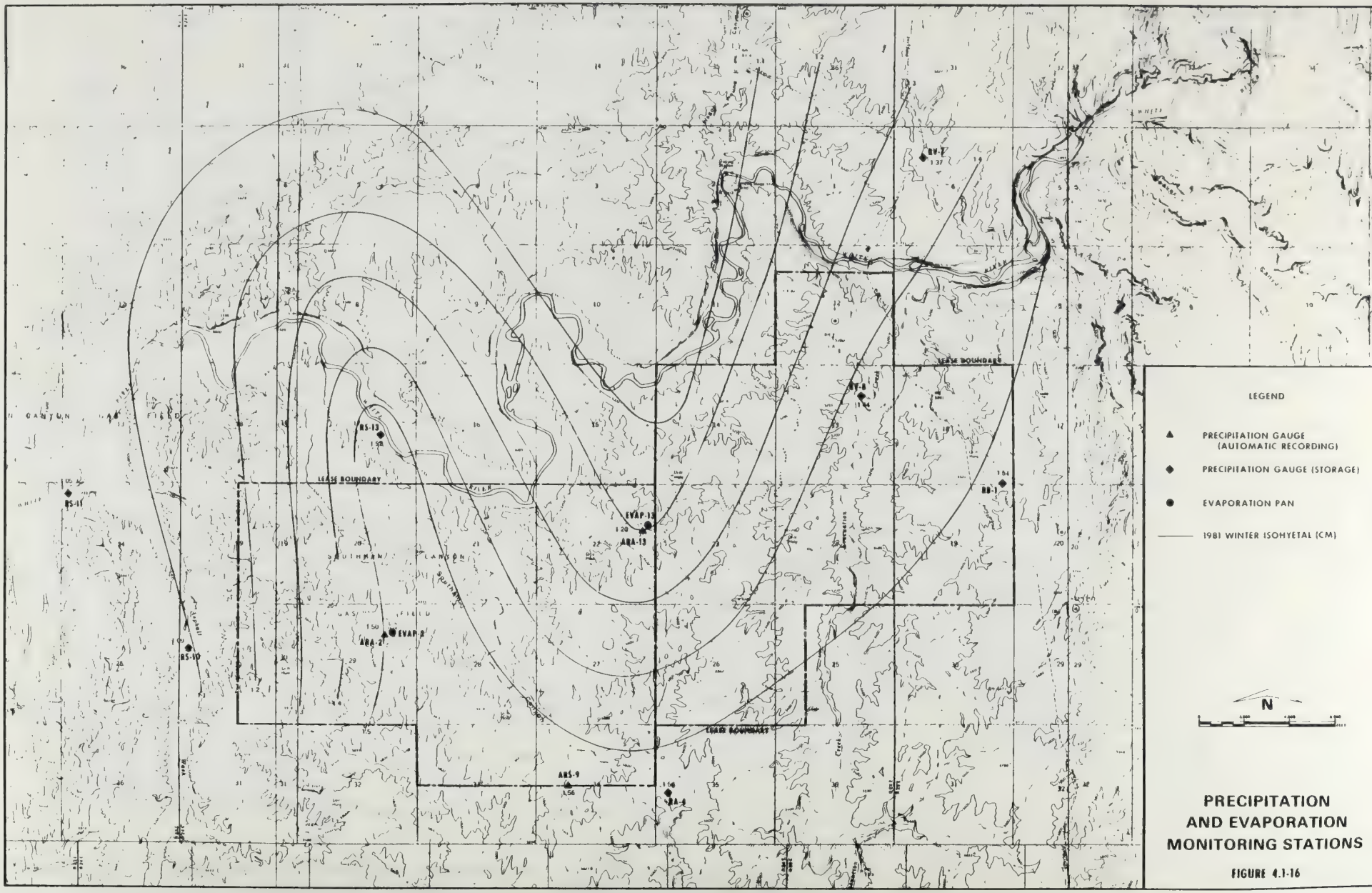
TABLE 4.1-19

MONTHLY AND SEASONAL PRECIPITATION VALUES
WHITE RIVER SHALE PROJECT

	Monthly Precipitation												Seasonal Totals				
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Fall	Wint	Sprg	Summ	Ann
ARA-2	0.70	0.50(a)	0.10(a)	0.30(a)	0.40(a)	0.80(a)	0.50	1.70	0.20	0.80	0.50	0.80	1.30	1.50	2.40	2.10	7.30
ARA-13	0.90	0.50	0.10	0.10	0.30	0.80	0.60	1.60	0.30	0.80	0.60	0.80	1.50	1.20	2.50	2.20	7.40
ARS-9	1.00	0.40(a)	0.30(a)	0.10(a)	0.30(a)	1.10(a)	0.70	1.60(b)	0.60	0.90	1.10	0.70	1.70	1.50	2.90	2.70	8.80
RA-4	0.96	0.43	0.28	0.12	0.33	1.11	0.80	1.83	0.53	1.05	1.03	0.80	1.67	1.56	3.16	2.88	9.27
RB-1	1.08(b)	0.55(b)	0.24(b)	0.22(b)	0.36(b)	0.93	0.78	1.63	0.43	0.79	0.94	0.97	1.87	1.51	2.84	2.70	8.92
RS-10	0.72(c)	0.39(c)	0.22(c)	0.27(c)	0.41(c)	0.14	0.41	1.04	0.33	0.76	0.60	0.76	1.33	1.09	1.78	2.12	6.32
RS-11	0.99	0.39	0.10	0.18	0.26	0.61	0.40	1.60	0.40	1.22	0.61	0.95	1.48	1.05	2.40	2.78	7.71
RS-13	0.97	0.63(d)	0.13(d)	0.13(d)	0.38(d)	1.01(d)	0.21	1.84	0.30	1.09	0.83	0.76	1.73	1.52	2.35	2.68	8.28
RV-7	1.08	0.39	0.20	0.13	0.28	0.96	0.75	1.74	0.25	0.49	0.43	1.30	1.67	1.37	2.74	2.22	8.00
RV-8	1.10	0.52	0.18	0.16	0.31	0.97	0.79	1.70	0.40	0.73	0.73	1.18	1.80	1.44	2.89	2.64	8.77

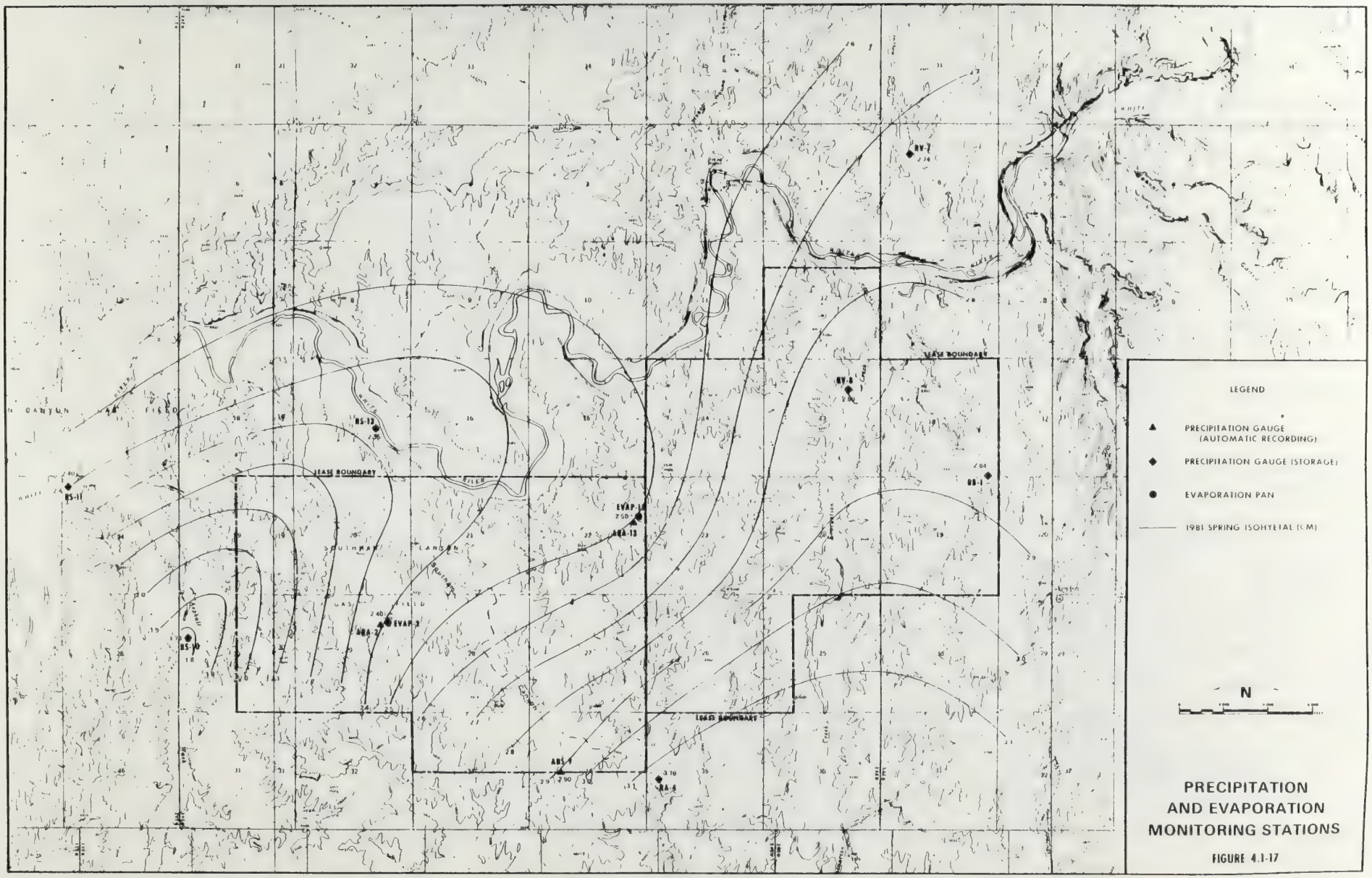
(a) Estimated from storage gauge.
(b) Estimated from tract data.
(c) Estimated from RS-11.
(d) Estimated from five-month storage.


LEGEND
PRECIPITATION GAUGE (AUTOMATIC RECORDING)
PRECIPITATION GAUGE (STORAGE)
EVAPORATION PAN
1981 FALL ISOHYETAL (CM)
N
LEASE BOUNDARY
CANYON
FIELD
SOUTHMAN
CANYON
GAS
FIELD
BS-13
BS-11
BS-10
ARA-2
EVAP-2
EVAP-1
ARA-13
ARS-9
ARA-4
RV-2
RV-1
RB-1
PRECIPITATION AND EVAPORATION MONITORING STATIONS
FIGURE 4.1-15



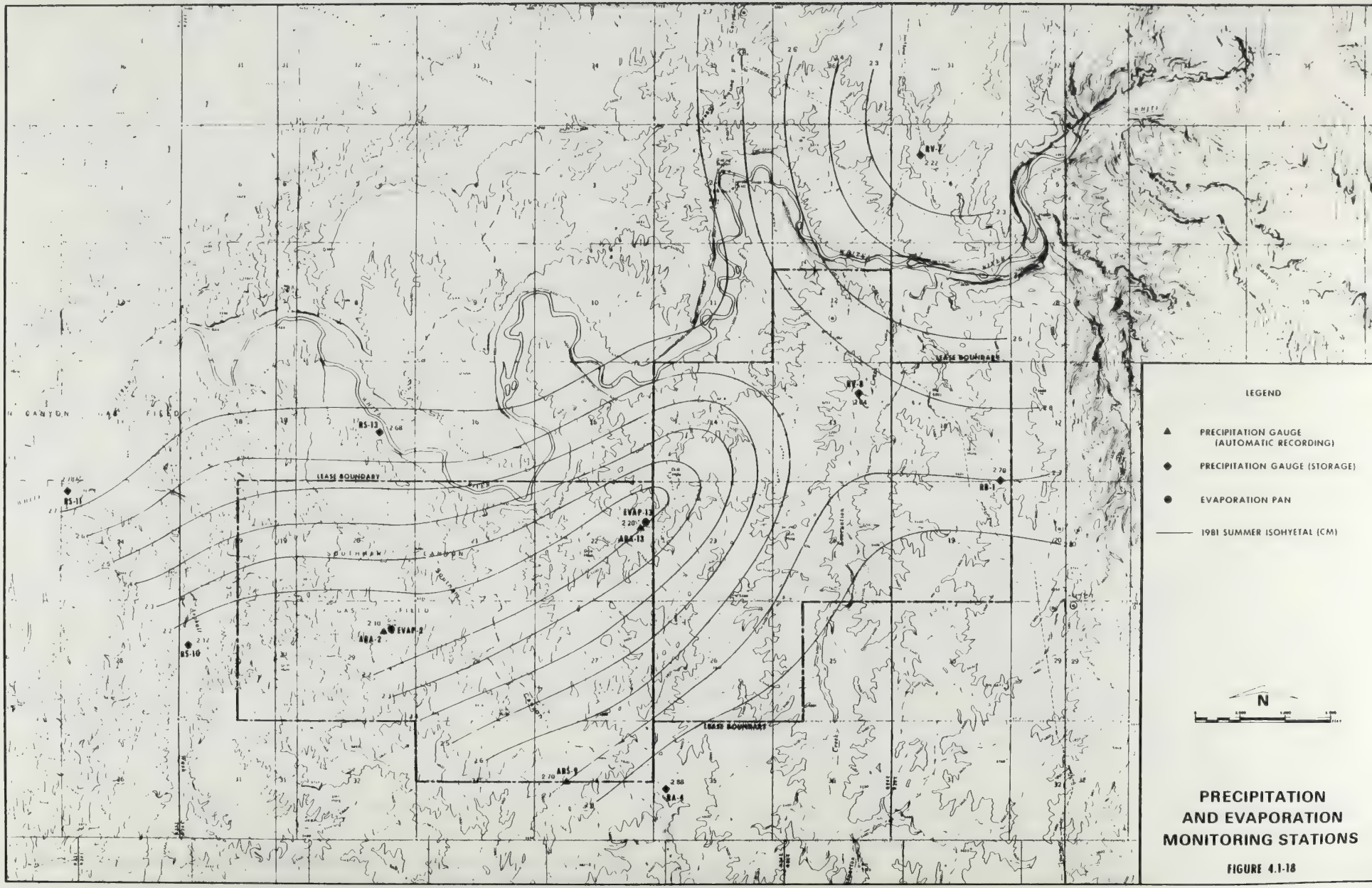
PRECIPITATION AND EVAPORATION MONITORING STATIONS

FIGURE 4.1-16



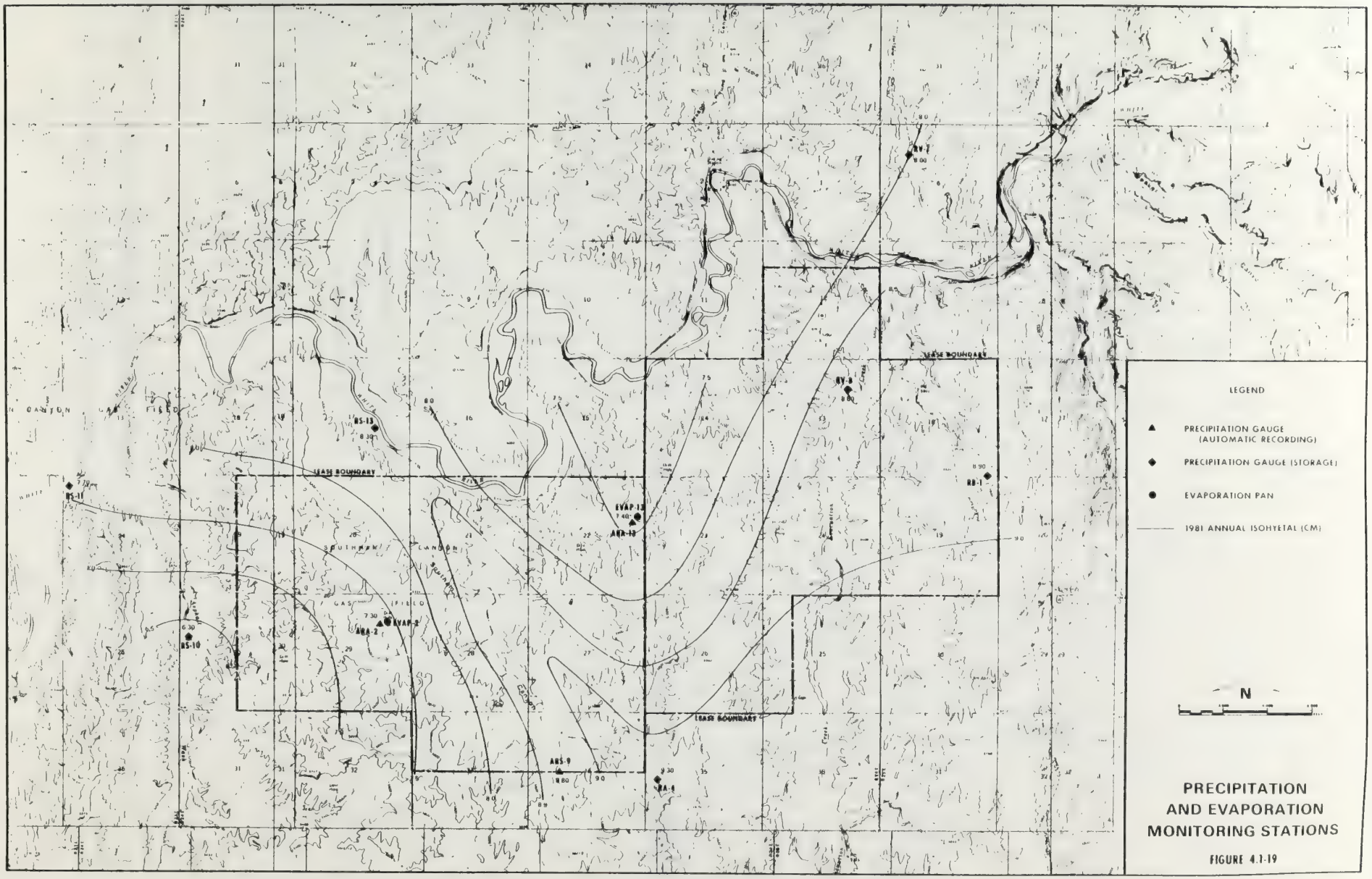
PRECIPITATION AND EVAPORATION MONITORING STATIONS

FIGURE 4.1-17



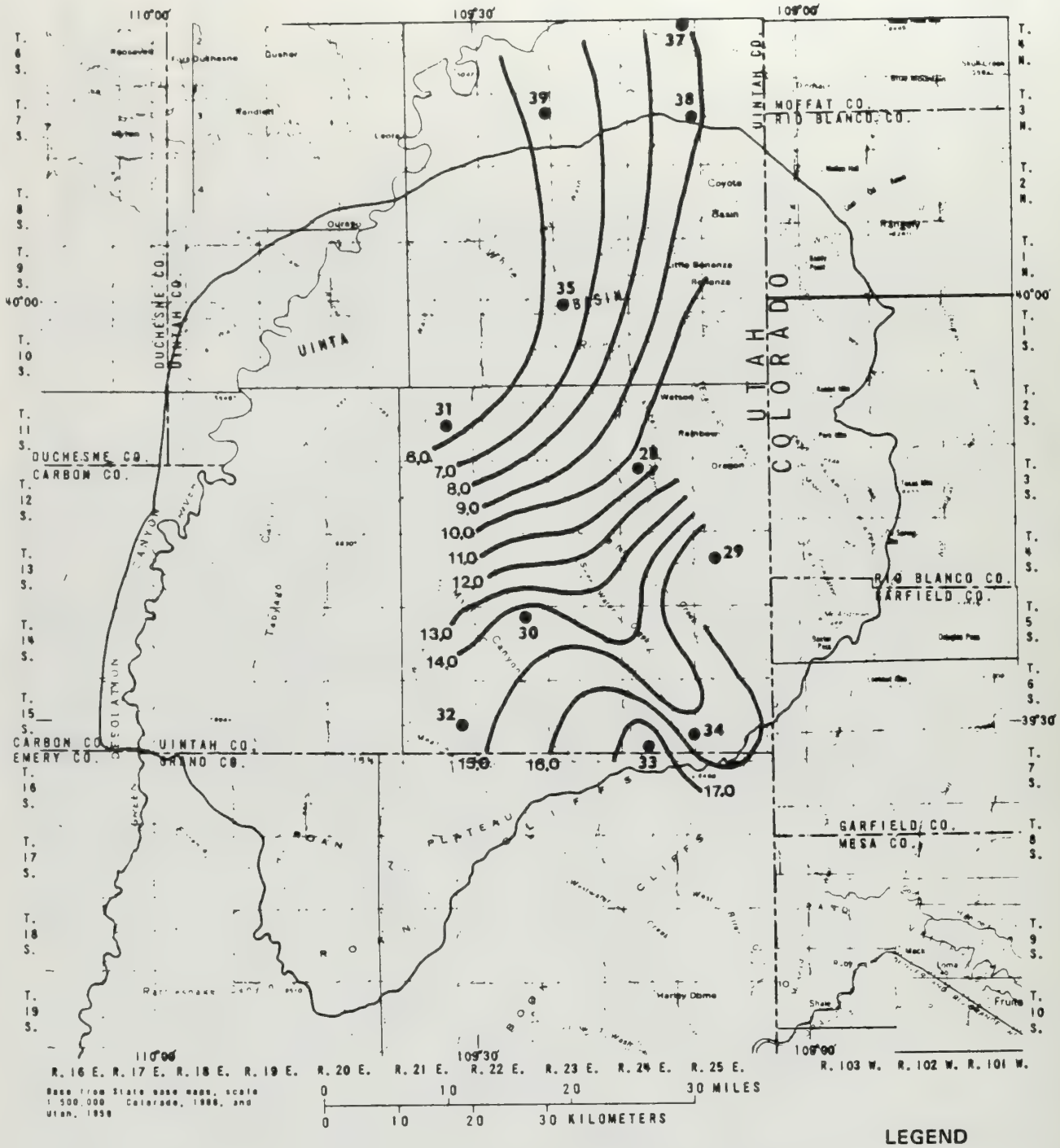
PRECIPITATION AND EVAPORATION MONITORING STATIONS

FIGURE 4.1-18



PRECIPITATION AND EVAPORATION MONITORING STATIONS

FIGURE 4.1-19



BLM REGIONAL PRECIPITATION NETWORK WITH
1981 WATER YEAR ANALYSIS

FIGURE 4.1-20

Evaporation

The evaporation data for stations EVP-2 and EVP-13 for the freeze-free period (May-September 1981) are shown in Table 4.1-20. The summary does not include data for months where the record is largely incomplete (i.e. October 1981). The total evaporation at EVP-2 and EVP-13 for this period was 28.06 inches and 25.62 inches, respectively.

4.1.4.4 Conclusions

Precipitation

Data collected prior to the 1981 water year indicated that the tracts received an annual average precipitation of nine to ten inches. Observations showed 1981, to be a dry year when the tracts received an average (geometric mean) of only 8.03 inches. Table 4.1-21 presents the annual precipitation data for the 1975 through 1981 water years. A comparison between the historic record and 1981 is shown in Table 4.1-22. While annual totals were distinctly lower in 1981, the previously observed patterns have continued. Specifically, precipitation was lower in the west and northwest portions of the tracts and gradually increased toward the southeast.

In addition to the normal climatologic studies, an analysis of site-specific precipitation/frequency relationships was conducted. The objective of the analysis was to determine if published regional data (NOAA Precipitation Frequency Atlas) on the 100-year return interval, 24-hour storm event was applicable to the White River Shale project

TABLE 4.1-20

MONTHLY TOTAL EVAPORATION
(Inches)

Station		May	Jun	Jul	Aug	Sep	Period
EVP-2	Net	2.25	7.23	6.40	6.28	4.48	26.64
	Precip.	0.60(a)	0.20	0.80	0.50	0.80	2.90
	Total(b)	2.70	7.06	6.84	6.44	5.02	28.06
EVP-13	Net	1.95	6.88	5.68	5.63	3.73	23.87
	Precip.	0.60(a)	0.30	0.80	0.60	0.80	3.10
	Total(b)	2.42	6.82	6.16	5.92	4.30	25.62

(a) May precipitation value is the total after May 8, when evaporation measurements began.

(b) Total evaporation equals (net + [May through Sep precipitation]) (0.95).

TABLE 4.1-21

ANNUAL PRECIPITATION FOR
WATER YEARS 1975 THROUGH 1981

Station	1975	1976	1977	1978	1979	1980	1981
ARA-2		9.60	6.00		9.91	10.52	7.30
ARA-13		9.20	6.00	6.50	10.33	9.50	7.40
ARS-9	10.59	10.21			11.29	10.33	8.80
RA-4					12.89	11.33	9.27
RB-1							8.92
RS-10							6.32
RS-11	8.14				10.57	8.20	7.71
RS-13	8.57	9.78			9.83	9.69	8.28
RV-7				8.10	10.30	9.22	8.00
RV-8	9.09			6.38	11.17	9.08	8.77
Average					10.75	9.69	8.03

TABLE 4.1-22

HISTORIC AND 1981 PRECIPITATION RECORD

Year	Tract Low	Tract High	Tract Average
Historic	9.00	11.00	10.00
1981	6.32	9.27	8.03

site. As the site-specific data base was relatively small, the analysis began with a review of one-year return interval storms of various durations. This review revealed that published data overestimates the short-duration events (e.g. 1 hour) and, more importantly, underestimates long-duration events (e.g. 24 hours). The second step in the analysis specifically addressed the 100-year, 24-hour storm. Two methods were employed to establish an upper and lower limit of the actual event. The upper and lower limits were determined to be 3.25 and 2.63 inches respectively. The published data indicated a value of 2.4 inches for this event, again showing an underestimation of the long duration event. The conclusion of the analysis was that, for hydrologic and engineering design work, the mean of the upper and lower limits, or 2.94 inches, should be used.

Evaporation

The 1981 water year provided additional data on the relationship between pan evaporation and exposure. It can be shown that the most significant controlling factor on pan evaporation was air flow. In 1980, the effects of natural (landform) obstructions were found to dramatically affect pan evaporation at the EVP-13 site. By relocating the pan at EVP-13, a site with better overall exposure, evaporation was increased by approximately 20%.

Subsequent to the initiation of the 1981 monitoring at EVP-2, a fence was placed around the site. This fencing acted as an artificial windbreak by disrupting air flow over the pan. The degree to which

evaporation at EVP-2 has been impacted was estimated by comparing the 1980 and 1981 data for both sites. For example, at EVP-13, a decrease in evaporation of approximately 0.46 inches (2% relative to 1980) occurred between 1980 and 1981 water years. As a result, EVP-2 was expected to show a similar percentage decrease. However, a decrease of almost 8.84 inches (24% relative to 1980) was observed, due probably to the installation of a cyclone-type fence that disrupted airflow over the evaporation pan. Although year to year trends at EVP-2 do not exactly correspond to EVP-13, it is estimated that the total evaporation at EVP-2 (if the fence were not present) would have been approximately equal to the 1980 value of 36.90 inches. This estimate is based on the comparison of 1980 vs. 1981 values at EVP-13.

ERRATA

Progress Report - 1979, Section 4.1

1. Table 4.1-6: One page of this table was inadvertently omitted from the report. Refer to USGS published water resources data for Utah during the 1979 water year.

2. Figure 4.1-16: P-2 lower elevations should be:

   - ground surface = 4,990.5
   - measuring point = 4,993.3

3. Table 4.1-19: Water level elevations as stated in the Table are inaccurate. They are based on depth below the measuring point (usually the top of well collar several feet above ground surface), and have not been corrected to reflect the distance between the measuring point and the ground surface. Same for Table 4.1-20 in 1980 Annual Report. Measuring point-to-ground elevation distances are being compiled for all monitoring wells and will appear with corrected water level elevations in future Errata.

4. Figure 4.1-17: Errors in water level elevations in Table 4.1-19 appear in the piezometric contour map and should be corrected. This will not significantly affect the contours as shown.

Progress Report - 1980, Section 4.1

1. Table 4.1-3: The August and September columns of mean daily streamflow are transposed.

2. Table 4.1-5: There are typographical errors in this table. Corrections are as follows:

   - Mean Daily Discharge for August 25 = 124 cfs
   - Mean Daily Discharge for August 26 = 20 cfs
   - Mean Daily Discharge for August 27 = 2.0 cfs
   - Mean Daily Discharge for August 28 = 0.00 cfs
   - Mean Discharge for Year = 0.93 cfs
   - Total Runoff for Year = 678 acre-feet

3. Figure 4.1-4: The lowest point of the vertical axis (streamflow in cfs) should be less than or equal to 1 cfs, rather than 0 cfs.

4. Page 4.1-31, lines 12 and 13: This sentence should read "The maximum instantaneous suspended sediment discharge was estimated to have been 1,047 tons/day on August 27," rather than "The maximum mean daily suspended sediment discharge..."

5. Table 4.1-14: Corrections to the table are as follows:

   - Mean Daily Discharge, 1977 Water Year = 8.67 cms/306 cfs
   - Maximum Daily discharge, 1977 Water Year = 17.7 cms/624 cfs
   - Minimum Daily Discharge, 1977 Water Year = 0.48 cms/17 cfs
   - Mean Daily Discharge, Sta. 6700, Period of Record = 18.3 cms/645 cfs
   - Minimum Daily Discharge, Sta. 6700, Period of Record = 0.48 cms/17 cfs

6. Table 4.1-17: Corrections to the table are as follows:

   - Mean Daily Discharge, 1980 Water Year = 0.0042 cms/0.15 cfs

7. Table 4.1-20: Note at the bottom of Table 4.1-20 should read "manually," not "annually." Total well depth of G-11 should read 650 feet, not 559 feet. Also see remark under 1979 Report, Table 4.1-19.

8. Figure 4.1-11: See remark under 1979 Report, Figure 4.1-17.

9. Page 4.1-52, line 9: The unit peak discharge at station 6625 for the period of record is 0.929 $m^3/sec/km^2$ (32.8 cfs/mi^2).

10. Table 4.1-27: It should be clarified that the values in this table for the non-standard evaporation pans at both the new and old sites do not represent actual pan evaporation values. They are meaningful only in terms of the relationship between the new and old sites.

AIR RESOURCES

4.2 AIR RESOURCES

A two-year baseline program began late in 1974 and was completed in January 1977. The baseline years referred to in this report are 1975 and 1976. An interim program went into effect in January 1977. The Interim Air Resources Monitoring Program was designed as a systematic step between the Baseline Monitoring Program and the Development Monitoring Program. Collection of data on pertinent air quality and meteorological parameters has continued. The Development Monitoring Program is expected to be implemented during 1982. From January 1977 through 1981, four monitoring stations (A4, A6, A11, and A13) collected meteorological data with one of these sites (A6) used additionally for air quality monitoring. Figure 4.2-1 shows the specific locations of the air quality and meteorological sites on the Ua-Ub tracts during 1981. Sound level measurements were resumed in October 1981.

Data for previous years were analyzed and summarized in previous progress reports (White River Shale Project Reports, 1976 through 1981). The data collected during the interim monitoring year 1981 are summarized and analyzed here. In addition, a discussion of the visibility data derived from photographs taken during the baseline is included.

4.2.1 Air Quality Monitoring Program

The Interim Air Quality Program was initiated on 16 January 1977. Objectives of this program were to determine if the occasional

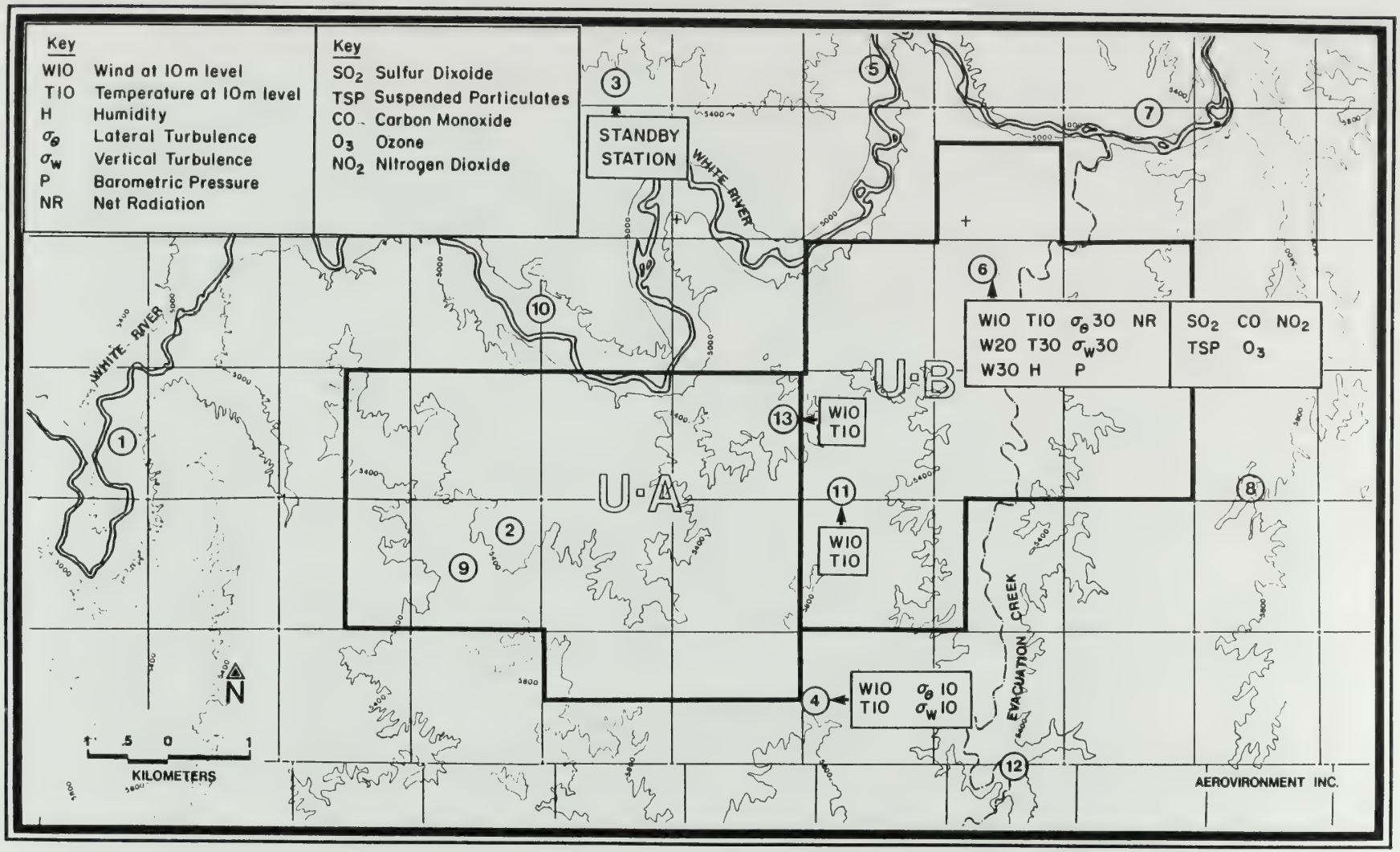


FIGURE 4.2-1. Locations of meteorological and air quality measurement stations on tracts Ua and Ub.

high levels of ozone noted during the baseline period would recur during the lease suspension period, to maintain continuity of data on other air quality parameters, and to note any significant deviations of values of these parameters from those observed during the Baseline Program.

Site A6 (see Figure 4.2-1) has continued to operate throughout the Baseline and Interim Programs. Table 4.2-1 lists the instruments used and the parameters measured during 1981. All instruments are in compliance with EPA regulations. Table 4.2-1 also shows detection limits and data precisions and validity of all the instruments. All parameters, except total suspended particulates, are monitored continuously. Data are recorded on digital punched tapes every six minutes and on strip charts every two minutes.

Total suspended particulates are measured over a 24-hour period at A6 every sixth day. This schedule is the same as used in the Baseline Monitoring Program and is considered sufficient for continued characterization of the randomly produced background particulate material levels.

4.2.1.1 Quality Assurance Program. Quality assurance provisions were fivefold. First, all instruments used during this year were internally audited three times (1-2 April, 28-29 July, 18-20 November, 1981). Internal audits have been performed on a quarterly basis including ones in December 1980 and January 1982. Second, the air quality instruments were recalibrated (dynamic

TABLE 4.2-1. Air quality monitoring equipment by parameter and the instrument lower detection limit, data precision, and lower limit of data validity during 1981.

Parameter	Monitoring Instrument	Instrument Lower Dectection Limit	Data Precision	Lower Limit of Data Validity
O_3	Monitor Labs Model 8410E ozone analyzer, chemiluminescence	2 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
CO	Monitor Labs Model 8310 infrared	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3
NO_x	Monitor Labs Model 8440E NO/NO_x analyzer, chemiluminescence	5 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
NO		5 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
$NO_2(NO_x-NO)$		5 $\mu g/m^3$	12 $\mu g/m^3$	12 $\mu g/m^3$
SO_2	Thermo Electron Corp. Model 43 pulsed fluorescent SO_2 analyzer	25 $\mu g/m^3$	8 $\mu g/m^3$	25 $\mu g/m^3$
TSP	Sierra Instruments Model GMWC-2000H, Hi-Vol with constant flow	0.5 $\mu g/m^3$	+ 6% of Toad or 1 $\mu g/m^3$	1 $\mu g/m^3$

multiple point) monthly. Third, the instruments were span and zero checked three times per week. Fourth, precision checks were made once every two weeks. Fifth, there was one EPA external audit (7-8 April, 1981). This calibration schedule is more rigorous than for the Baseline Program, reflecting the greater reliability demanded of a single air monitoring station. The quality assurance program is described in depth in the report "Quality Assurance Plan for Air Resources Monitoring, Oil Shale Lease Tracts Ua-Ub" (AV-QA8047R2, AeroVironment Inc., 1982).

The air quality parameters monitored during 1981 are listed in Table 4.2-2, along with the percentage of time each parameter was monitored. For TSP, the calculation was based on data collected by the designated TSP sampler and not the collocated sampler.

4.2.1.2 Data Summary

Gaseous Pollutants

Both gaseous and particulate air quality are measured at Site A6. Utah state air quality standards for gaseous pollutants are the same as the federal standards. For reference in the ensuing discussions, Table 4.2-3 gives the Utah State and National Ambient Air Quality Standards (NAAQS) for the various gaseous pollutants monitored on the tracts.

The air on the tracts was very clear of gaseous pollutants. The only pollutant present in measurable quantities was ozone, which has a natural non-zero background level. Otherwise, almost all instru-

TABLE 4.2-2. Percentage of time air quality parameters were monitored during 1 January - 31 December 1981.

Component	Number of Stations	Percentage of Time Monitored
SO_2	1	98
NO_x	1	95
O_3	1	98
CO	1	98
Suspended Particulates	1	95

TABLE 4.2-3. National and Utah air quality standards for gaseous pollutants.

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Ozone (O_3)	1-hour	240 $\mu g/m^3$ (0.12 ppm)	Same as primary
Carbon Monoxide (CO)	8-hour	10 mg/m^3 (9 ppm)	Same as primary
	1-hour	40 mg/m^3 (35 ppm)	Same as primary
Sulfur Dioxide (SO_2)	annual average	80 $\mu g/m^3$ (0.03 ppm)	-
	24-hour	365 $\mu g/m^3$ (0.14 ppm)	-
	3-hour	-	1300 $\mu g/m^3$ (0.5 ppm)
Nitrogen Dioxide (NO_2)	annual average	100 $\mu g/m^3$ (0.05 ppm)	Same as primary

ments measuring gaseous pollutants were recording at their threshold limit most of the time, the same situation as found during the baseline period.

The 1981 data were compared with the baseline (1975-1976) or long-term (1975-1980) data. Generally, the data exhibit no significant abnormalities with respect to earlier data. When appropriate, specific comments accompany the discussion of each parameter.

1. Ozone (O_3)

Trends of the diurnal variation of O_3 at Site A6 for January and July 1981 and baseline are shown in Figure 4.2-2. The daily minimum occurs in the early morning, while the daily maximum occurs in the afternoon. The biggest difference between the maximum and minimum ozone values occurs in July and the smallest difference in January.

Table 4.2-4 gives the monthly averages of ozone for 1981 compared to the baseline averages. January and February 1981 ozone values were much lower than baseline. During these two months, there were only seven frontal passages and most of these were dry and weak and none of them produced high ozone. The majority of the time the area was under the influence of warm high pressure cells. For the rest of the year, the monthly averages were comparable to those of past years.

The seasonal highest hourly concentration, second highest hourly concentration, and seasonal averages for O_3 are given in Table 4.2-5. The highest and second highest values for 1981 were

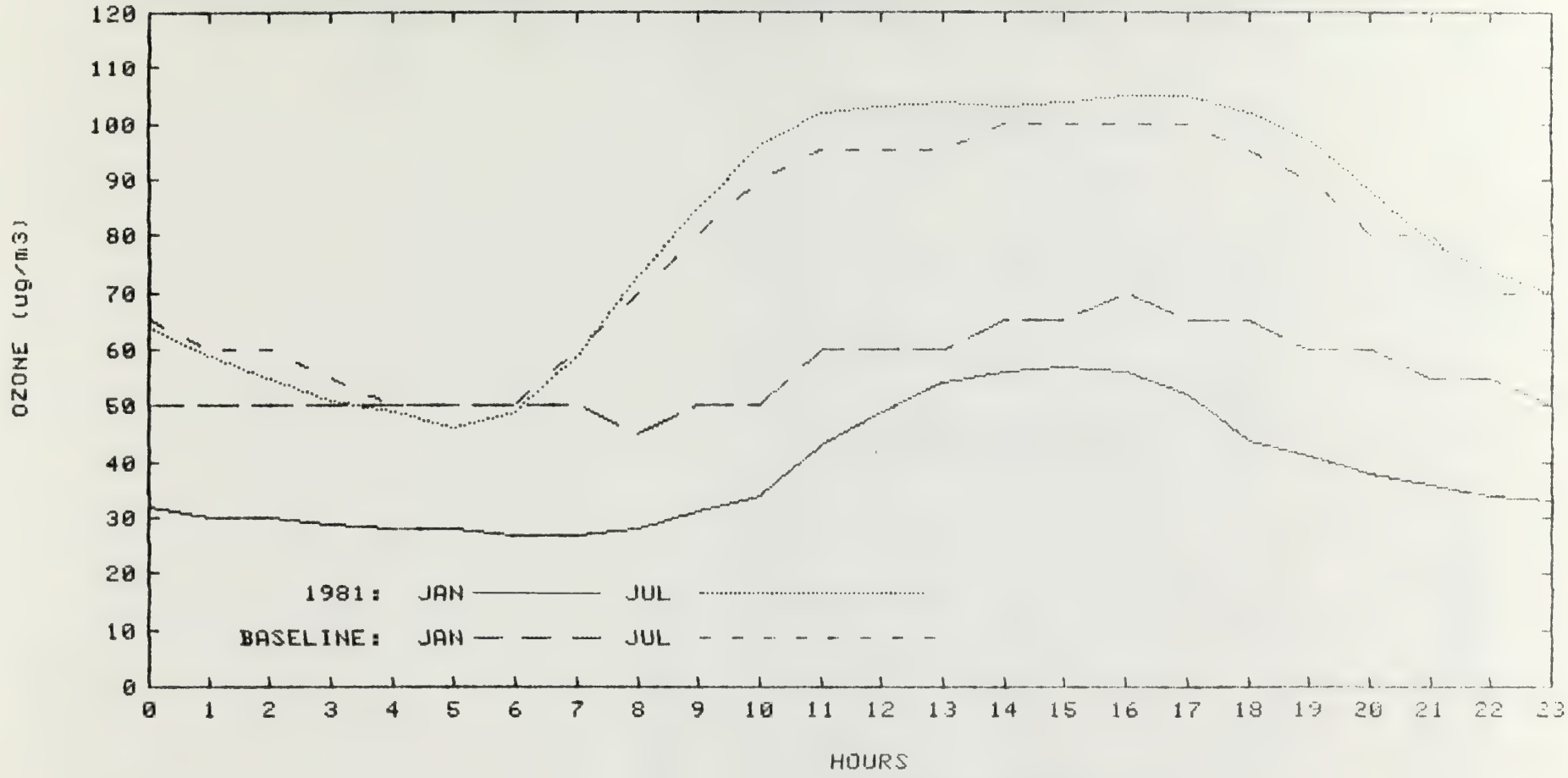


FIGURE 4.2-2 Diurnal variation of mean ozone concentrations at Site A6 during January and July 1981 and January and July of the baseline period.

TABLE 4.2-4. Monthly average of 1981 O_3 ($\mu g/m^3$) compared to baseline values.

Month	Baseline	1981
Jan	60*	38
Feb	70	49
Mar	70	57
Apr	80	75
May	75	74
Jun	70	69
Jul	80	80
Aug	70	89
Sep	65	80
Oct	55	58
Nov	45	50
Dec	50	59
Annual	67	65

*January 1976 only.

TABLE 4.2-5. Comparison of the seasonal highest and 1-hour O_3 readings (in g/m^3), as well as the seasonal averages at Site A6 for the baseline period (1975-1976) and 1981.

Season	Peak Concentration		Second Highest Concentration		Seasonal Average	
	Baseline	1981	Baseline	1981	Baseline	1981
Winter	150	116	150	112	70	49
Spring	150	125	140	125	75	69
Summer	140	148	140	145	75	79
Fall	140	136	120	134	55	63

148 $\mu g/m^3$ and 145 $\mu g/m^3$. These values were recorded during July. The 1981 seasonal values were lower than those observed during winter and spring compared to baseline, and higher during the summer and fall seasons. The nominal detection limit for the ozone analyzer is 2 $\mu g/m^3$ and the instrument's validity limit is $\pm$ 6 $\mu g/m^3$.

Figure 4.2-3 shows the monthly maximum hourly values and means, as well as the mean daily maximum hourly averages for 1981 compared to the baseline period. The highest maximums and means in the summer. The lowest averages occur during late fall and early winter. The monthly maximum values for July, August, October, November, and December were higher than baseline values. The mean daily maximum hourly averages from January through April had lower values than baseline.

Figure 4.2-4 shows the trend of monthly averaged ozone from February 1975 through December 1981. The highest monthly average of 96 $\mu g/m^3$ occurred in February 1979. That month was very cold and stormy with an unusual amount of ozone intrusion accompanying frontal passages. The Fall months of October and November are generally the lowest with peak values during the late spring, early summer months.

Figure 4.2-5 shows the trend in the annual averages of ozone at Site A6 since 1975.

Figure 4.2-6 is an annual ozone pollution rose at Site A6 for 1981. The majority of low O_3 concentrations ($\leq$50 $\mu g/m^3$) occur with the wind blowing from the east-southeast. This is the nighttime

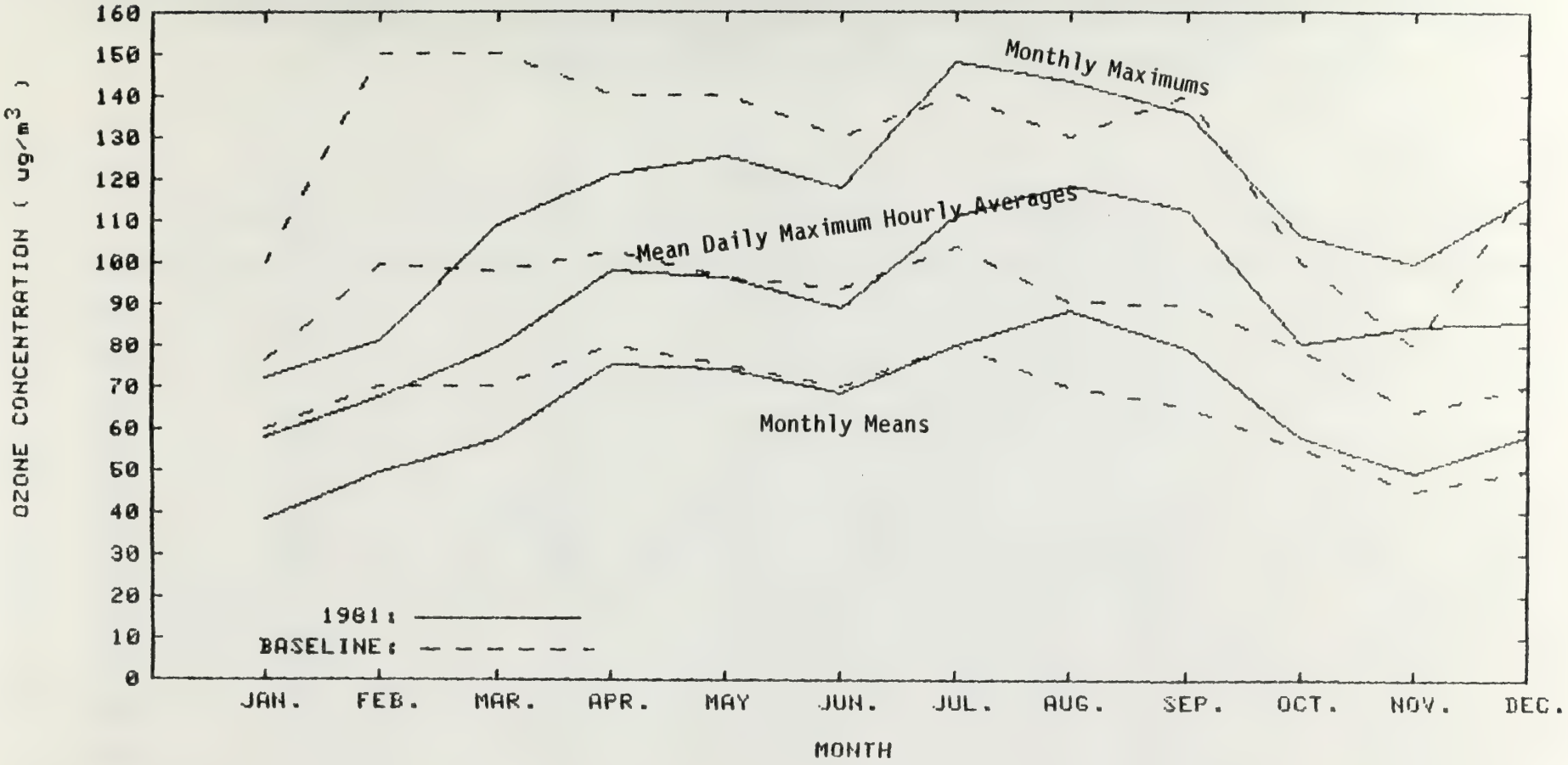


FIGURE 4.2-3. Monthly maximum hourly values, mean daily maximum hourly averages, and mean monthly values of O_3 at Site A6 during 1981 and the baseline period.

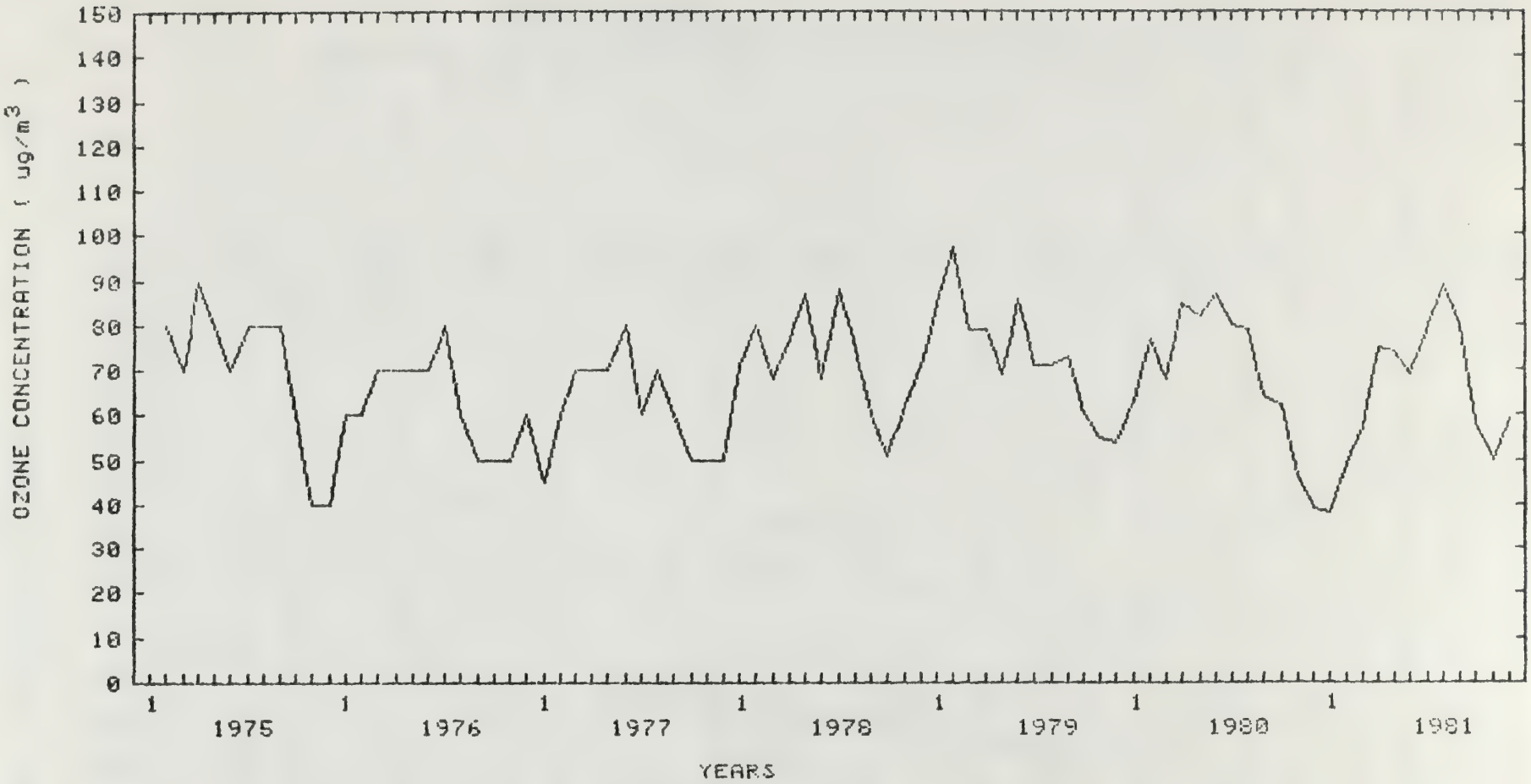


FIGURE 4.2-4. Trend of monthly average ozone at Site A6 from February 1975 to December 1981.

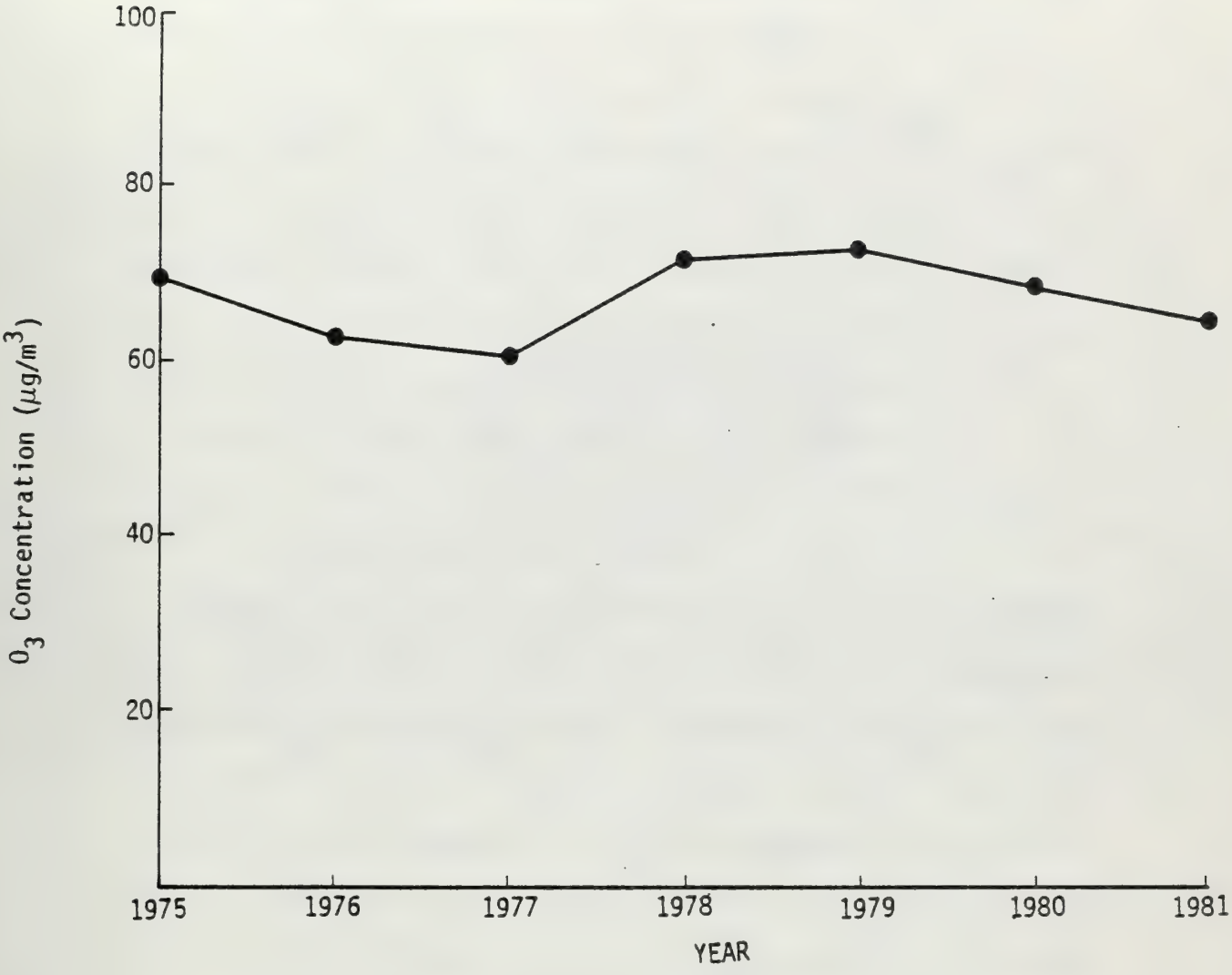


FIGURE 4.2-5. Trend of annual average O_3 at Site A6.

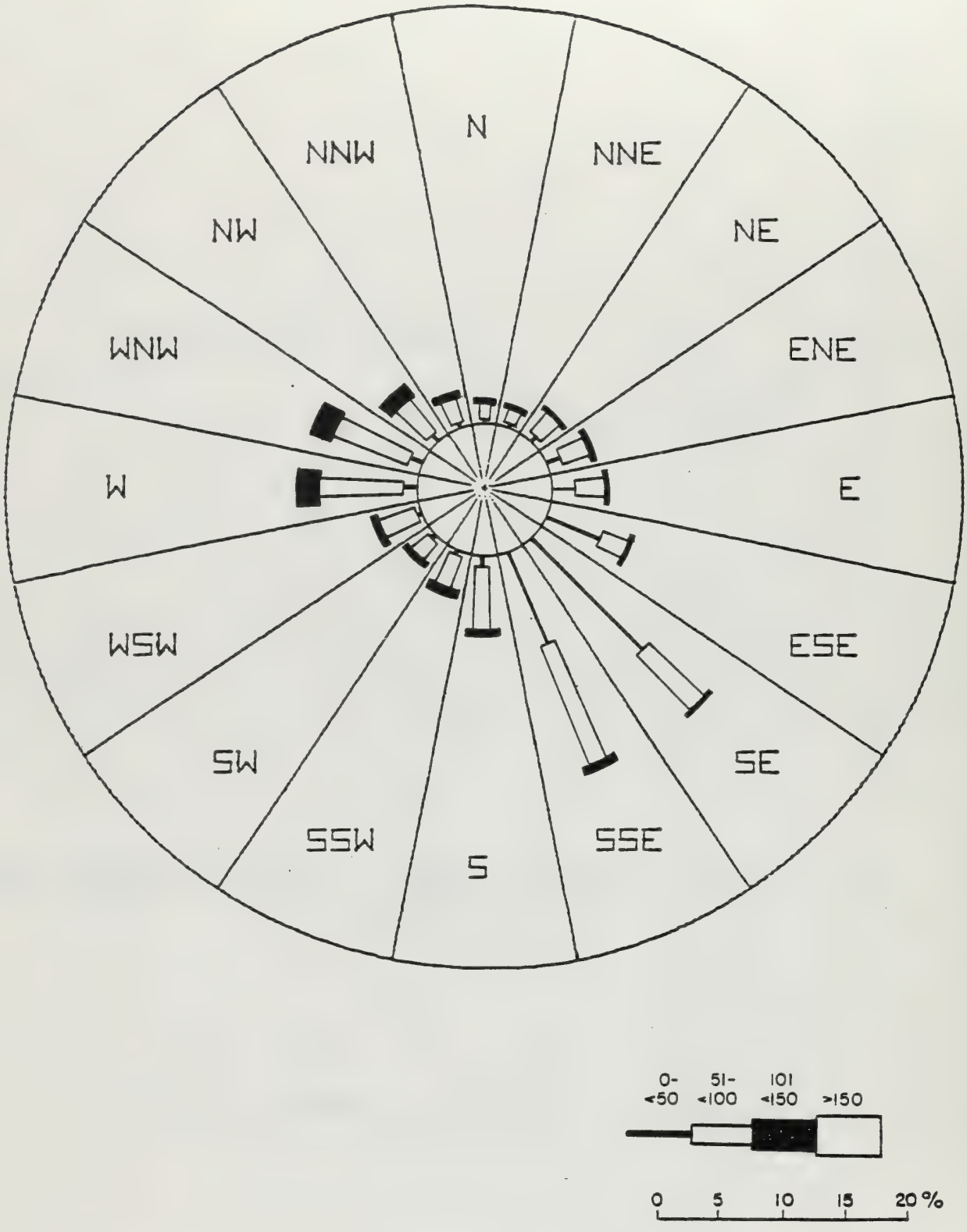


FIGURE 4.2-6. Annual ozone pollution rose at Site A6.

drainage flow. The highest values (100 to 150 $\mu g/m^3$) occur with the wind from a variety of directions. This would tend to rule out local precursors and denote influxes of ozone from natural origins.

According to Chan and Smith (1981), the ozone concentrations at Site A6 depend a great deal on the ozone content of the troposphere. Year-to-year variability correlates with the passage of fronts over the site. Unusually high ozone concentrations (>100 $\mu g/m^3$) can be attributed to ozone intrustions accompanying frontal passages, strong turbulent atmospheric mixing that brings ozone from aloft to the surface, or long-range transport from urban areas.

2. Carbon Monoxide (CO)

Table 4.2-6 gives the highest, second highest, and average one-hour and eight-hour CO concentrations at Site A6 for each season. During 1981, the maximum one-hour concentration was 1.5 mg $/m^3$ and the maximum eight-hour reading was 1.3 mg/m^3. These are lower than the 3.0 mg/m^3 and 1.8 mg/m^3 recorded during the baseline period. Most of the values are near zero and even though the values may appear to increase this year, overall CO levels have not changed appreciably. The difference in concentrations between the 1981 and the baseline value might be attributable to the difference of the analyzers used for the two periods. All values are well-below the national standards of 40 mg/m^3 (one-hour) and 10 mg/m^3 (eight-hour).

The normal background level is 0.5 mg/m^3 and practically all the readings fall around or below this value. No diurnal or seasonal

TABLE 4.2-6. Comparisons of the seasonal highest and second highest 1-hour and 8-hour moving mean CO readings (in mg/m^3), as well as the seasonal averages at Site A6 for the baseline period (1975-1976) and 1981.

Season	Averaging Time	Peak Concentration		Second Highest Concentration		Seasonal Average	
		Baseline	1981	Baseline	1981	Baseline	1981
Winter	1-hour	3.0	1.4	2.2	1.4	0.2	0.4
	8-hour	1.3	1.2	1.2	1.2		
Spring	1-hour	0.8	1.3	0.7	1.3	0.1	0.5
	8-hour	0.7	1.3	0.5	1.3		
Summer	1-hour	3.0	1.5	2.7	1.4	0.1	0.5
	8-hour	1.8	1.3	1.7	1.3		
Fall	1-hour	1.2	0.6	1.2	0.5	0.2	0.0
	8-hour	0.7	0.5	0.6	0.5		

variations are observed in the CO levels. Readings are generally near the detection limit of the instrument, 0.1 mg/m^3.

3. Nitrogen Dioxide (NO_2)

Of the nitrogen oxides, only NO_2 has a national ambient air quality standard (annual average of 100 $\mu g/m^3$). Table 4.2-7 shows the seasonal highest, second highest, and seasonal averages for both the baseline period and 1981. The California standard (for reference) is a one-hour average of 470 $\mu g/m^3$. This table also shows the annual averages. Again, activity on the tracts during the first part of the Baseline Program could have produced the high values of 100 $\mu g/m^3$.

The precision of the instrument is around 12 $\mu g/m^3$ and readings are generally below this value and near the lower detection limit of this instrument (5 $\mu g/m^3$). The highest and second highest one-hour values during 1981 were 14 and 13 $\mu g/m^3$, recorded during the winter season.

4. Sulfur Dioxide, SO_2

Table 4.2-8 compares the 1981 and baseline periods' highest, second highest, and seasonal averages for both the three-hour and 24-hour readings of SO_2. No seasonal or diurnal trend is evident and most values are near or below the detection limit of the instrument, 25 $\mu g/m^3$. The highest three-hour SO_2 reading of 24 $\mu g/m^3$ was recorded during the summer of 1981. The standard for a three-hour

TABLE 4.2-7. Comparisons of the seasonal highest and second highest one-hour NO_2 concentrations ($\mu g/m^3$) as well as the seasonal averages at Site A6 for the baseline period (1975-1976) and 1981.

Season	Peak Concentration		Second Highest Concentration		Seasonal Average	
	Baseline	1981	Baseline	1981	Baseline	1981
Winter	30	14	30	13	2	2
Spring	20	9	20	8	2	1
Summer	100	6	90	6	12	1
Fall	100	12	80	11	5	1
Annual	100	14	90	13	5	1

TABLE 4.2-8. Comparisons of the seasonal highest and second highest 3-hourly and 24-hourly-averaged SO_2 concentrations ($\mu g/m^3$), as well as the seasonal averages at Site A6 during the baseline period (1975-1976) and 1981.

Season	Averaging Time	Peak Concentration		Second Highest Concentration		Seasonal Average	
		Baseline	1981	Baseline	1981	Baseline	1981
Winter	3-hour	10	14	8	14	1	4
	24-hour	5	13	5	10		
Spring	3-hour	10	16	10	15	1	7
	24-hour	5	11	5	11		
Summer	3-hour	15	24	12	24	3	9
	24-hour	10	19	10	18		
Fall	3-hour	7	23	7	22	1	9
	24-hour	5	16	5	16		

averaging time is 1,300 $\mu g/m^3$. The highest 24-hour SO_2 reading was 19 $\mu g/m^3$, recorded during the summer. Again, this reading is well below the 24-hour standard of 365 $\mu g/m^3$. The annual average on the tracts has always been $<10 \mu g/m^3$, compared to the annual standard of 80 $\mu g/m^3$.

Total Suspended Particulate (TSP)

Particulate concentrations are monitored by high volume samplers which sample over a period of 24 hours once every six days. The size of the particulate matter collected by the samplers ranges from below 1 μm to 100 μm. Two TSP samplers are operated at Site A6, one called the designator and the other called the collocator.

The collocator was established to allow the determination of the precision of the TSP data. The accuracy of the data was determined through periodic audits. Standard procedures for calculating the precision and accuracy are detailed in the PSD guidelines Sections 6.3.2.1 and 6.3.2.2 (U.S. EPA, 1978). They also appear in 44 Federal Register 27477 (May 1979).

Table 4.2-9 shows the computed precision and accuracy of the TSP samples during days when both samplers were operating. This table includes only those days when both samplers were operating simultaneously for 24 hours. The wide range of the 95% confidence limits during the April-June and October-December quarters is attributed to the low concentrations recorded. A difference in 1 $\mu g/m^3$ at values less than 20 $\mu g/m^3$ are significant, whereas at

TABLE 4.2-9. Precision and accuracy of the TSP samplers at Site 6 during 1981.

Reporting Period	Precision		Confidence Limit		Accuracy	
	No. of Collected Samples	No. of Official Samples $<20\ \mu g/m^3$	Lower 95%	Upper 95%	Audit Date	Percent Difference (Di)*
JAN-MAR	15	7	-12.43	14.729	12/5/80	-3.82
APR-JUN	15	9	-24.21	26.646	4/2/81	0.00
JUL-SEP	10	3	-5.530	17.385	6/29/81	-0.20
OCT-DEC	16	11	-25.43	27.004	11/20/81	-0.02

$$*Di = \frac{Yi-Xi}{Xi}\ 100$$

Xi -- known flow rate (m^3/min)

Yi -- audit flow rate (m^3/min)

higher values, the percent difference would not be as significant. Some incomplete samples of the collocator during the summer months were not included in the precision computations. Four internal audits for accuracy (December 1980, April, July, and November, 1981) were conducted in 1981. Audit results of the designator sampler are also shown in Table 4.2-9.

Table 4.2-10 gives the geometric mean, standard geometric deviation, maximum and minimum of the total suspended particulate concentrations in $\mu g/m^3$ at Site A6. The baseline period and 1981 values are shown by season.

The geometric mean given can be considered to correspond to the concentration expected at a 50% frequency because particulate concentrations are generally lognormally distributed. The geometric mean particulate concentration during 1981 ranged from 15.0 $\mu g/m^3$ during the spring months to 28.6 $\mu g/m^3$ during the summer. The maximum 24-hour value for 1981 was 80.4 $\mu g/m^3$ recorded on 20 September 1981.

None of the recorded values exceeded national or state standards, which are given in Table 4.2-11. The most stringent short-term standard is the National Secondary Standard, which sets the upper limit at 150 $\mu g/m^3$, averaged over 24 hours; this is not to be exceeded more than once a year.

4.2.1.3 Background Averages Table 4.2-12 gives the annual averages for the pollutants monitored on the tracts from 1975

TABLE 4.2-10. Geometric means, standard geometric deviations, and maximum and minimum particulate concentrations ($\mu g/m^3$) for baseline period (1975, 1976) and 1981 at Site A6.

	Season	Baseline	1981
Geometric Mean	Winter	14.2*	16.4
	Spring	17.2	15.0
	Summer	37.0	28.6
	Fall	27.2	18.8
Standard Geometric Deviation	Winter	2.6*	2.0
	Spring	1.9	1.4
	Summer	1.4	1.5
	Fall	2.0	2.5
Maximum	Winter	51.9*	30.4
	Spring	42.0	27.4
	Summer	74.7	72.6
	Fall	101.2	80.4
Minimum	Winter	3.5*	3.6
	Spring	4.9	7.2
	Summer	18.7	16.6
	Fall	4.9	4.5
Geometric Mean	Annual	24.0	19.1
Standard Geometric Deviation	Annual	2.5	1.9

*1976 only, insufficient data for 1975.

TABLE 4.2-11. National and Utah state ambient air quality standards for particulate matter ($\mu g/m^3$).

Pollutant	Averaging Time	Standards	
		Primary	Secondary
Suspended Particulate Matter	Annual Geometric Mean	75	60
	24-hour	260	150

Pollutant	Baseline		Annual Averages				
					Interim		
	1975	1976	1977	1978	1979	1980	1981
O_3	70	63	61	72	73	69	65
CO (mg/m^3)	.2	.1	.2	.1	.1	.4	.3
NO_2	5	5	0	1	1	2	1
SO_2	3	0	1	3	0	1	7
TSP	24.5	23.5	22.2	15.0	12.5	19.6	19.1

TABLE 4.2-12. The annual averages ($\mu g/m^3$) for the gaseous pollutants and annual geometric mean for TSP during the entire period of monitoring.

through 1981. Generally, the values were slightly lower during the last four years. The values recorded during the interim period are more representative of true background conditions since during this time activities on the tracts were at a minimum.

The changes in the annual geometric means for TSP during the past six years seem to be related to the changes in annual average wind speeds on the tracts at Site A6. The annual average wind speeds from 1975 through 1981 were 4.0, 4.2, 3.1, 2.8, 2.9, 3.1 and 2.9 m/s, respectively.

4.2.1.4 Visibility Photographs of a number of targets were taken on a scheduled basis during the period April 1975 through January 1977. Three photographs were taken on one pre-selected day per month, at 0800, 1200, and 1600 Mountain Standard Time. These photographs have been analyzed with two purposes in mind: (1) to determine whether certain key targets were visible and (2) to compute visual range based on the apparent contrast between the sky and a key target.

The first approach also involved a subjective determination of whether the target was clearly visible, i.e. whether the visual ranges appeared to be at least 10% greater than the distance to the target.

The second approach, the computation of visual range, involved quantifying apparent target/sky contrast from black and white negatives by use of a densitometer.

The film density of the target and sky images and of a 10-step gray scale in the camera field of view on another photograph from the same roll were measured. Since the exposure value of the gray scale was known, a density versus exposure characteristic curve was developed for each roll. The target and sky density values fell in the range of the gray scale, so that target and sky exposure values could be derived. The visual range was then derived using the formula:

$$L_v = \frac{-3.912}{\ln\left(1 - \frac{E_t}{E_h}\right)} r$$

where:

L_v = visual range

r = target distance

E_t, E_h = exposure values of target and sky

This relationship assumes:

(1) a human eye contrast threshold of -0.02

(2) a black target

(The visual range determined in accordance with these conditions is often called the "meteorological range". It can be considered to reflect the greatest distance at which a typical observer can detect the presence of a target under idealized conditions.)

Visual ranges derived in this manner are sensitive to target and sky illumination, and are rigorously correct only when the sky is clear or covered with a high, uniform overcast, and the target is perfectly black. Nevertheless, the above formula provides a satisfactory approximation for many real sky conditions and dark targets.

The coefficient of 3.912 is valid if the film has the same spectral response as the human eye; the black-and-white film and filter combination used here roughly matched the human response, to a degree that is satisfactory for our purposes.

Integrating nephelometer data were collected at Site A2 at the same time as the photographs were taken. These data were related to visual range by the formula:

$$L_V = \frac{4.7}{b_{scat}}$$

where:

L_V = visual range

b_{scat} = scattering coefficient measured

The coefficient of 4.7 is specific for the spectral response of the Meteorology Research Model 1550 nephelometer used at Site A2, when measuring a reasonable aerosol size distribution. The assumptions inherent in this formula are the same as for the corresponding densitometric formula. In addition, this formula assumes that the scattering of light by the atmosphere is uniform, i.e. that the atmosphere is homogeneous throughout the visual field, which is only approximately true when the actual sight path to an elevated target such as a mountain is slanted upward through the atmosphere.

The data resulting from the two types of photographic analyses and the nephelometer calculations are summarized in Table 4.2-13. The determination of whether key targets are visible indicates that visual ranges exceeded 48 km on every observation save one, and that visual ranges exceeded 137 km on nearly 60% of the observations. The data derived from the densitometry method indicate that visual ranges exceed 75 km on every observation save one, 150 km on nearly 60% of the cases examined, and 400 km on 15% of the cases examined. (The longest visibility possible through the atmosphere is determined by the scattering of light by air molecules. For the average air density between the observation site at 1600 m elevation and the target at 2500 m, this limit is about 450 km for a spectral response comparable to that of the eye.)

The nephelometer data in Table 4.2-13 show, in general, somewhat lower visual ranges than those calculated from the photographs, with visual ranges exceeding 50, 100, and 235 km (the particle free atmospheric visibility limit at an elevation of 1600 m for the wavelength at which the integrating nephelometer operates) during 98, 67, and 5% of the cases, respectively. This difference between the methods is an expected result for two reasons: (1) The nephelometer samples air relatively near the ground, where the concentration of particles is greatest, while the photographic sight paths to elevated targets pass through cleaner air higher above the surface; and (2) the nephelometer observes the scattering of light by air molecules at an elevation of 1600 m, while the densitometry

TABLE 4.2-13 Summary of visual range data derived from photographs.

Target Visible Test

Target Distance (km)	Target Direction	Number of Photographs Analyzed	No. of Cases Where Target Was	
			Visible	Clearly Visible
48	North	61	60	37
112	West	61	50	2
137	Northwest	61	36	1
All 3 Targets		61	35	1

Calculated Visual Range (Densitometry)

Target Distance (km)	Target Direction	Number of Cases*	No. of Cases Where Visual Range Exceeded:		
			75km	150km	400km
48	North	51	50	30	8

Nephelometer Visual Range

No. of Obser-vations	No. of Cases Where Visual Range Exceeded				
	50km	75km	100km	150km	235km
58	57	49	39	18	3

* Cases of snow-covered target not considered.

sight path was through less dense air at an average height of about 2100 m, and the sight paths to the more distant targets at ranges beyond 100 km necessarily had an average elevation above 2500 m. Both of these differences decrease in importance as the visual range decreases.

Figure 4.2-7 displays the data of Table 4.2-13 in the form of a cumulative frequency distribution, plotted on log-probability scales. The nephelometer data plot as a straight line, showing the log-normal distribution that is typical of air pollution data. The photographic data derived by both methods, seem to lie along a parallel line, with visual ranges over the central part of the range 35% greater than the nephelometer values. The limited sample size results in scatter and the typical derivation from log-normal behavior at the two ends of the photographic data plot.

The frequency distribution plots show that the two photographic methods both indicate median (50% probability) visual ranges of about 160 km, while the nephelometric method deduced a median near-surface visual range of 120 km. The visual range fell below 50 km roughly 2% of the time, based on all methods; for 25% of the observations, the photographic visual ranges exceeded 200 km and the nephelometric values exceeded 160 km.

4.2.2 Meteorological Monitoring Program

Meteorological monitoring equipment at the four sites during 1981 has remained identical to that used during the two-year base-line period.

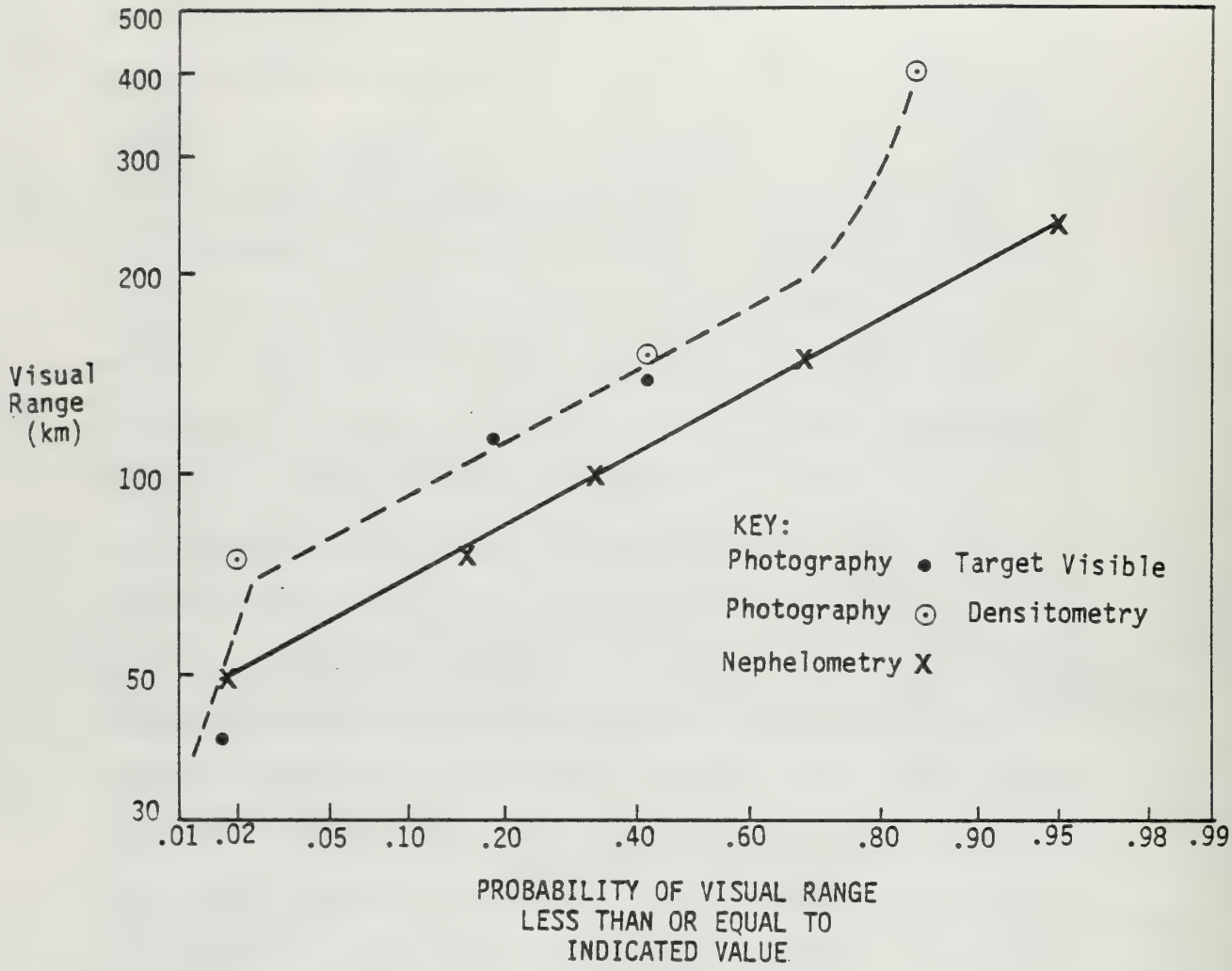


FIGURE 4.2-7. Cumulative frequency distribution of visual ranges derived from photographs and from integrating nephelometer measurements.

The objectives of continuing the meteorological measurements in the Interim Monitoring Program are to extend the meteorological data base, determine trends, and to provide verification of baseline data for future air pollutant dispersion modeling work.

The meteorological parameters monitored are shown in Table 4.2-14. Meteorological data are collected continuously and recorded on digital punch tapes every six minutes. Strip charts are also used at Sites A4 and A6 for backup records.

Table 4.2-15 lists the meteorological monitoring equipment used. Table 4.2-16 lists the percentages of data recovered for each meteorological parameter monitored on the tracts.

4.2.2.1 Quality Assurance Program. In accordance with the Quality Assurance Plan (AeroVironment Inc., 1982) the quality assurance procedures for meteorological instruments were followed during this period. For some meteorological instruments, off-site calibration is done annually and calibrations checked quarterly.

4.2.2.2 Climatic Regimes. Before discussing the details of the transport and dispersion characteristics of the atmosphere over the Ua-Ub tracts, it would be appropriate to summarize the major weather systems that affect the large scale movement of air masses over the area.

The horizontal transport of an air mass is a consequence of large-scale differences in air pressure. The factor determining

TABLE 4.2-14. Meteorological parameters monitored during 1981.

Parameter	Station			
	A4	A6	A11	A13
Meteorology				
WS/WD - 10 m	X	X	X	X
WS/WD - 20 m		X		
WS/WD - 30 m		X		
T - 10 m	X	X	X	X
T - 30 m		X		
ΔT - 10-30 m		X		
σ_θ - 10 m	X			
σ_θ - 30 m		X		
σ_w - 10 m	X			
σ_w - 30 m		X		
Net thermal radiation		X		
Dew point		X		
Relative humidity		X		
Barometric pressure		X		

TABLE 4.2-15. Meteorological monitoring equipment by parameter and the instrument lower detection limit, data precision, and lower limit of data validity during 1981.

Parameter	Monitoring Equipment	Instrument Lower Detection Limit	Data Precision	Lower Limit of Data Validity
Wind Speed	Meteorology Research Inc. Model 1022 anemometer (Sites 4, 6)	1 m/s	0.2 m/s	1 m/s
	Meteorology Research Inc. Model 1071 anemometer (Sites 11, 13)	1 m/s	0.2 m/s	1 m/s
Wind Direction	Meteorology Research Inc. Model 1022 anemometer (Sites 4, 6)	N/A	5%	N/A
	Meteorology Research Inc. Model 1071 anemometer (Sites 11, 13)	N/A	5^{o}	N/A
Temperature	Meteorology Research Inc. Model 840 (Sites 4,6)	$-30^{o}C$	$0.5^{o}C$	$-30^{o}C$
	Meteorology Research Inc. Model 1071 thermistor (Sites 11, 13)	$-34^{o}C$	1^{o}	$-34^{o}C$
Delta Temperature	Meteorology Research Inc. Model 840 thermistor	N/A	$0.2^{o}C$	1^{o}
Sigma Theta	Meteorology Research Inc. Model 1022 with sigma processor	0.5^{o}	1^{o}	N/A
Sigma W	R.M. Young Model 27100, with AV sigma processor	0.05 m/s	0.05 m/s	0.05 m/s
Barometric Pressure	Science Associates No. 370	600 mm Hg	0.5 mm Hg	600 mm Hg
Net Thermal Radiation	Fritschen net radiometer	-0.40 Ly/min	0.05 Ly/min	-0.40 Ly/min
Relative Humidity	WeatherMeasure Inc. H321-S	0%	5%	5%

TABLE 4.2-16. Percentage of data recovered for meteorological parameters during 1 January - 31 December 1981.

Component	Number of Stations	Percentage
Wind (10m)	4	96.2
Wind (20m)	1	98.9
Wind (30m)	1	99.1
Temperature (10m)	4	89.7
Δ Temperature (30-10m)	1	69.0
Relative Humidity	1	98.6
Sigma Theta	2	99.2
Sigma W	2	80.8
Net Thermal Radiation	1	97.4
Barometric Pressure	1	99.9

Utah's weather during the winter months is the location and strength of the Intermountain Region High Pressure Cell. Figure 4.2-8a shows the normal January sea level pressure and temperature. Storm tracks during mid-winter tend to pass north through Montana and through southern Utah. After February, storm tracks are more prevalent over northern Utah as the strength of the Basin High wanes. Precipitation is highest during the spring months.

During the summer months (Figure 4.2-8b), the pressure is lower and sporadic moisture from the Gulf of Mexico brings periods of scattered thundershowers. Beginning September, the storm fronts from the north increase in probability but are interspersed with many periods of clear weather when high pressure builds up in the Intermountain Basin.

Synoptic Summary - 1981

Generally, on the tracts during 1981, the barometric pressure was close to normal from January through May and then lower than normal pressure prevailed. The pressure pattern for the summer months were somewhat similar to Figure 4.2-8b. There were several periods of thunder storm activity during the June through September period, especially the month of August.

Soon after the first of October, the increasing frequency of storm fronts brought cooler temperatures, but November and December were basically clear with above normal temperature accompanied by normal precipitation, and the pressure pattern showed several instances of high pressure in the Basin.

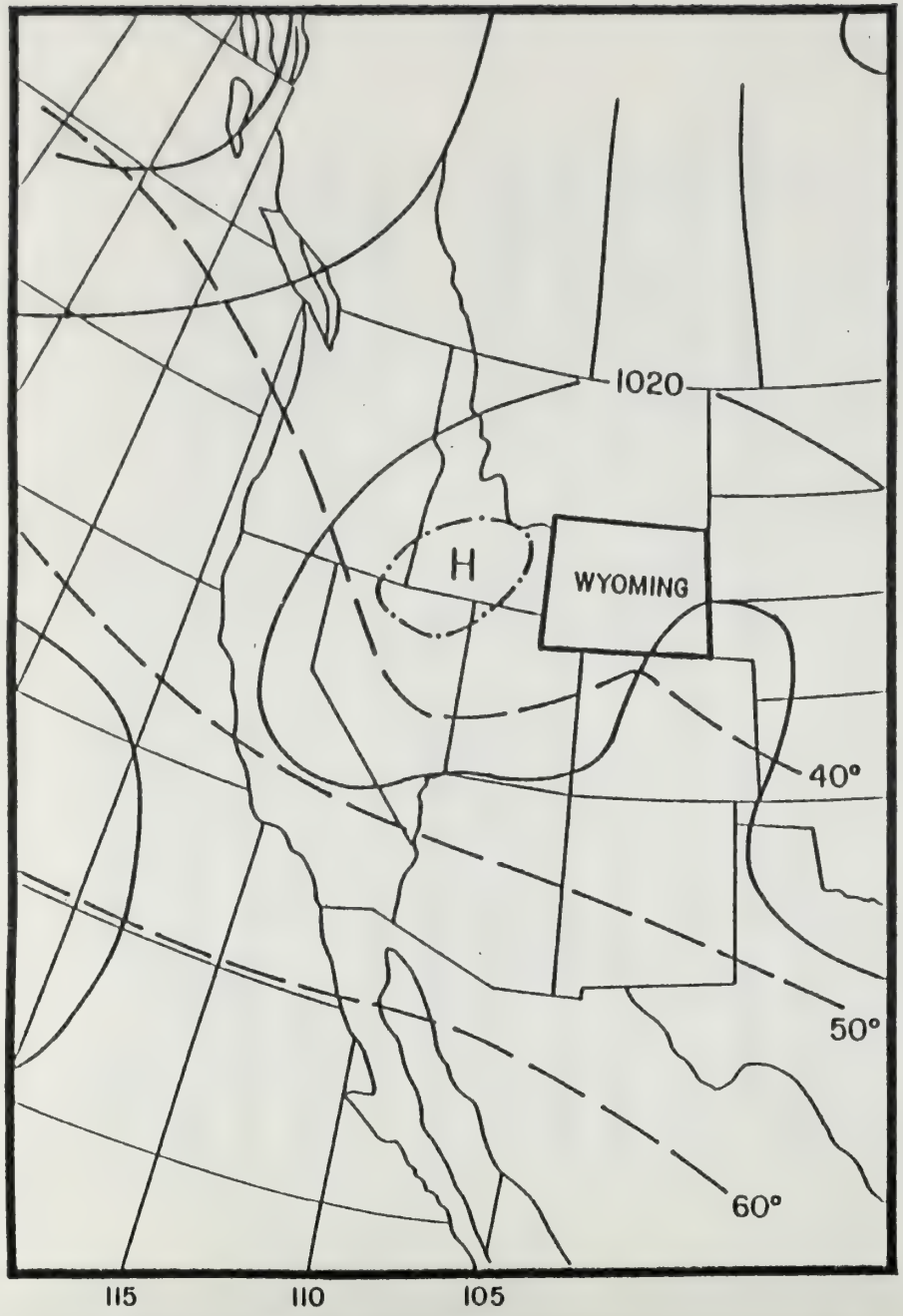


FIGURE 4.2-8a. Normal January Sea Level Pressure (solid lines) in mb and the temperature in ^{0}F (dashed lines).

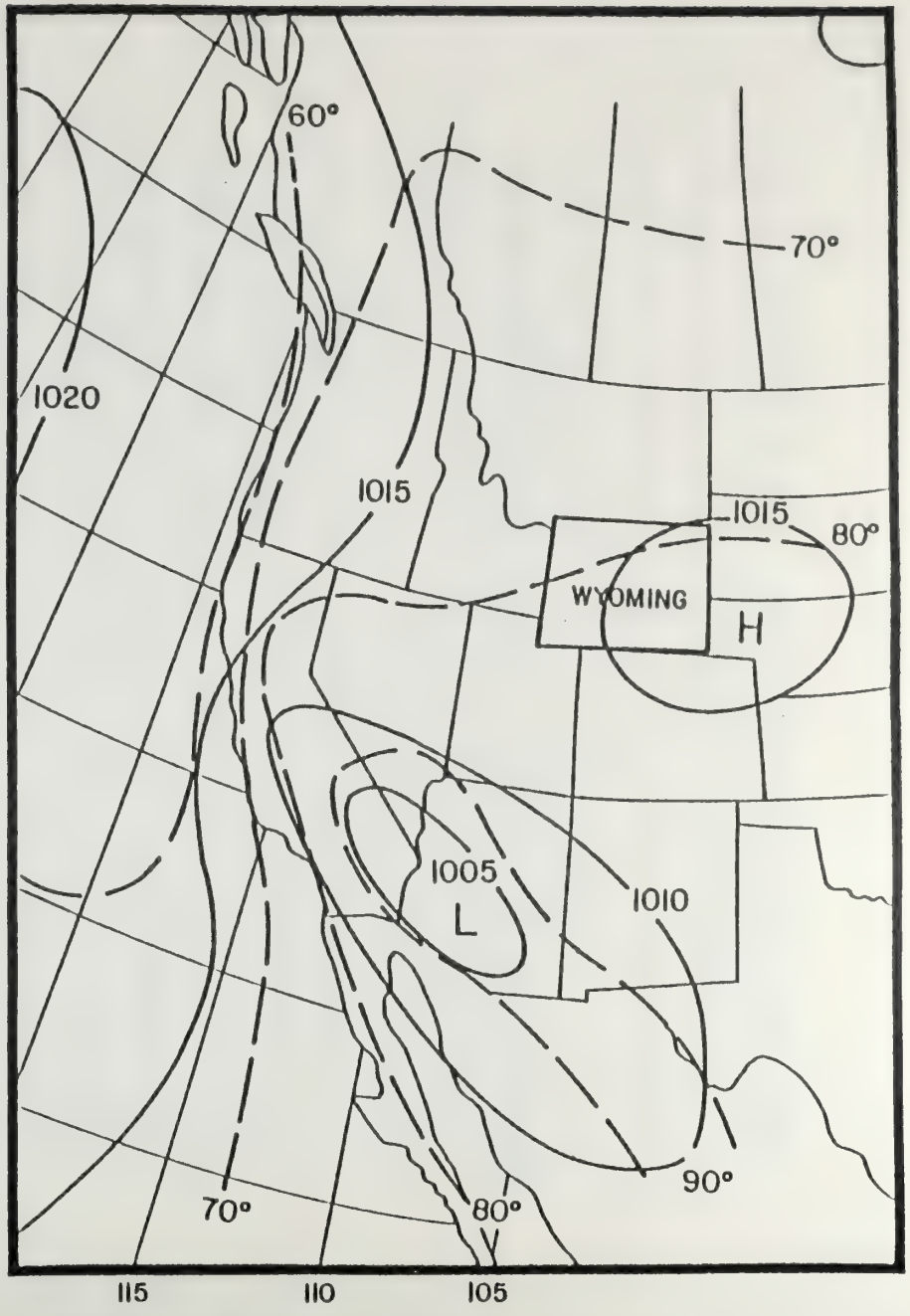


FIGURE 4.2-8b. Normal July sea level pressure (solid lines) in mb and temperature in ^{0}F (dashed lines).

4.2.2.3 Meteorological Data Summary. A summary of meteorological data for 1981 is presented below and compared quantitatively with the Baseline (1975-1976) Program data to determine any significant changes.

Surface Flow

As usual, the rugged terrain features in the area complicated the airflow pattern. Table 4.2-17 shows the prevailing direction and speed by month for the four wind sites. Spatial variation in wind speed on the tracts was also observed through the baseline period. Generally, nighttime drainage flow is prevalent throughout the year. Figure 4.2-9 shows the typical airflow streamlines for the early morning drainage pattern. The solid arrows on this figure are wind vectors at the monitoring sites, and the longer lines are estimated flow streamlines. The large open arrow depicts the mesoscale flow direction in the greater White River drainage basin. The drainage pattern does not deviate significantly throughout the year. This figure was prepared from averaged wind observations in 1981 at the four wind sites, plus knowledge of the wind flow pattern as presented in reports prepared for the baseline and interim periods. The drainage flow is always from higher to lower terrain, as noted during the baseline period.

Figure 4.2-10 shows an upslope pattern that is transitional between drainage and synoptic flow. The surface-based inversion that results from strong radiative cooling begins to lose some of its

TABLE 4.2-17. The monthly and annual prevailing wind direction/speeds (in m/s) at sites A4, A6, A11, and A13 during 1981.

Month	Site			
	A4	A6	A11	A13
Jan	W/1.9	SE/2.1	SE/2.1	S/1.1
Feb	W/2.5	SE/2.6	SE/2.8	SSE/1.7
Mar	SSE/2.8	SSE/2.9	SE/3.1	SSE/1.9
Apr	SSW/3.4	SSE/3.5	SE/3.5	SSE/2.5
May	SE/3.3	SSE/3.5	SE/3.5	SSE/2.8
Jun	W/3.7	W/4.0	NW/4.0	WNW/3.1
Jul	WNW/3.0	SSE/3.5	SE/3.3	SSE/2.5
Aug	SE/2.9	SSE/3.2	SE/3.2	SSE/2.5
Sep	WNW/2.8	SSE/3.1	SE/3.0	SSE/2.2
Oct	SSE/2.4	SSE/2.5	SSE/2.8	SSE/2.8
Nov	W/1.7	SE/1.7	SE/2.1	SSE/1.1
Dec	WSW/2.2	SE/1.9	SE/2.2	SE/1.4
Annual	W/2.7	SSE/2.9	SE/3.0	SSE/2.1

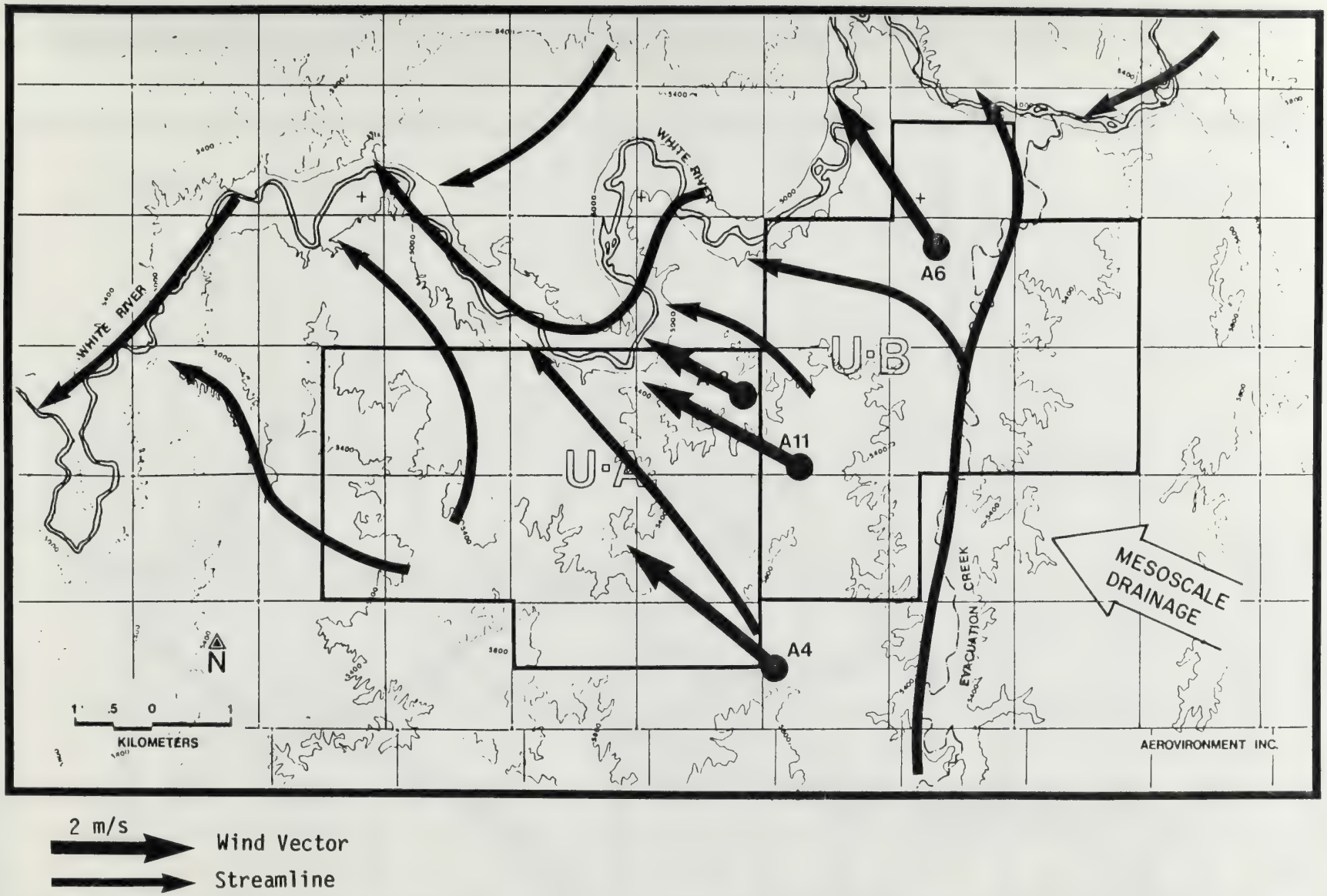
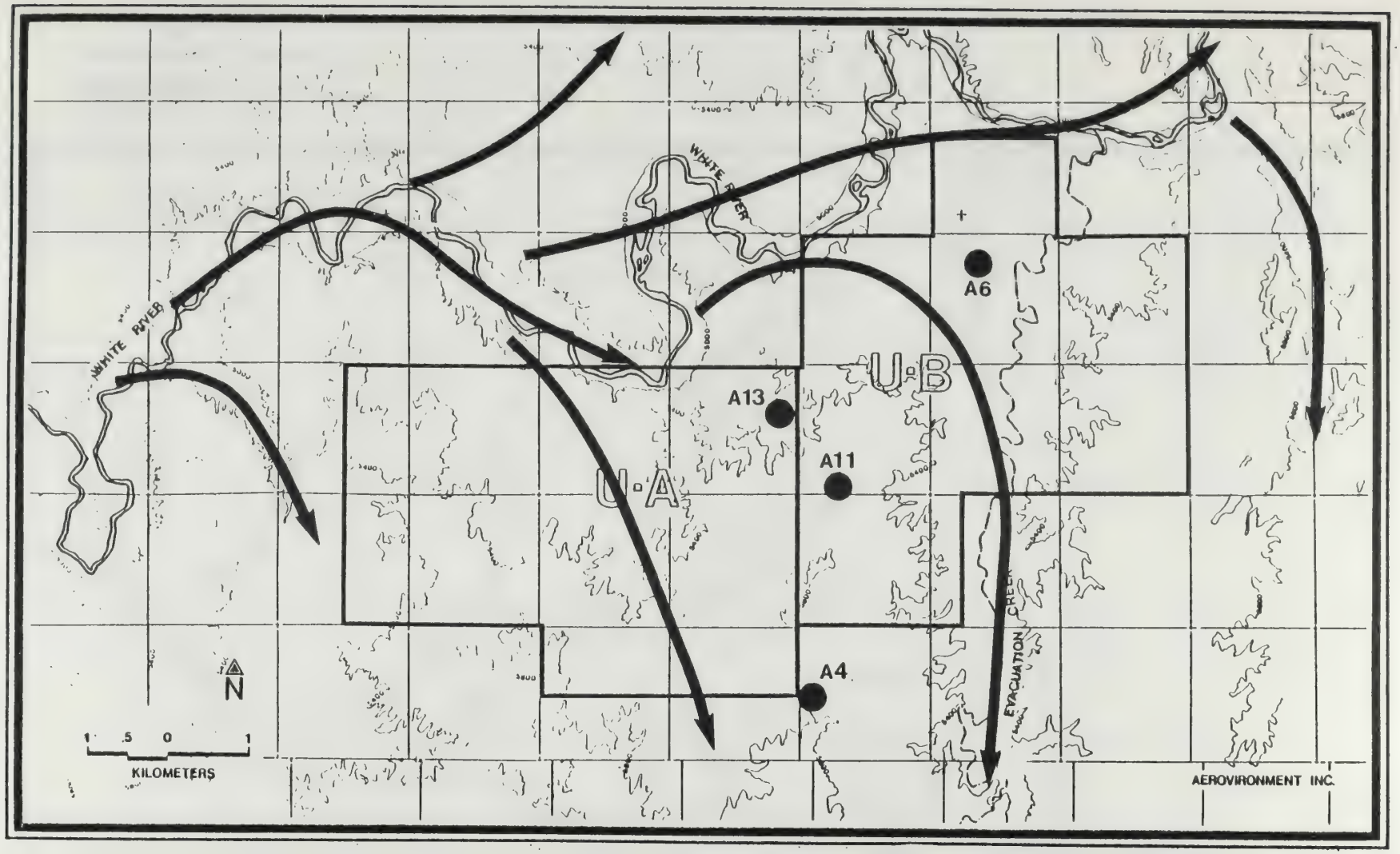


FIGURE 4.2-9. Typical drainage flow pattern on Tracts Ua and Ub during the early morning hours.



Streamline

FIGURE 4.2-10. Typical airflow pattern on Tracts Ua and Ub during the transitional period.

strength shortly after sunrise. As the morning progresses, the heat gained by the surface from solar radiation exceeds that lost by terrestrial radiation and the soil temperature rises, warming the air above. This creates a pressure difference resulting in upslope flow. This pattern is transitional and generally lasts less than an hour, but is important in understanding pollutant dispersion since plume fumigation would occur under this condition. Because of its brevity, this pattern is lost in the hourly-average wind direction. This pattern begins earlier during the summer months than during the winter when the sun rises later.

Figure 4.2-11 shows afternoon streamlines on the tracts during 1981. Very little directional difference is noted except the average speeds are higher during the summer. No significant difference from the baseline period is noted. This is the average synoptically-induced flow encountered in this portion of Utah throughout the year.

Figures 4.2-12 and 4.2-13 give the average hourly wind speeds for January and July 1981. January 1981 wind speeds are lower than the baseline averages. The July diurnal wind speeds are practically the same as the baseline averages.

Figures 4.2-14 through 4.2-17 show the directional wind roses at the monitoring stations on the tracts using the mid-month of the four seasons (January, April, July, and October 1981). Although individual months may show different prevailing directions, SSE and SE has been the most prevalent direction at Site A6 throughout the

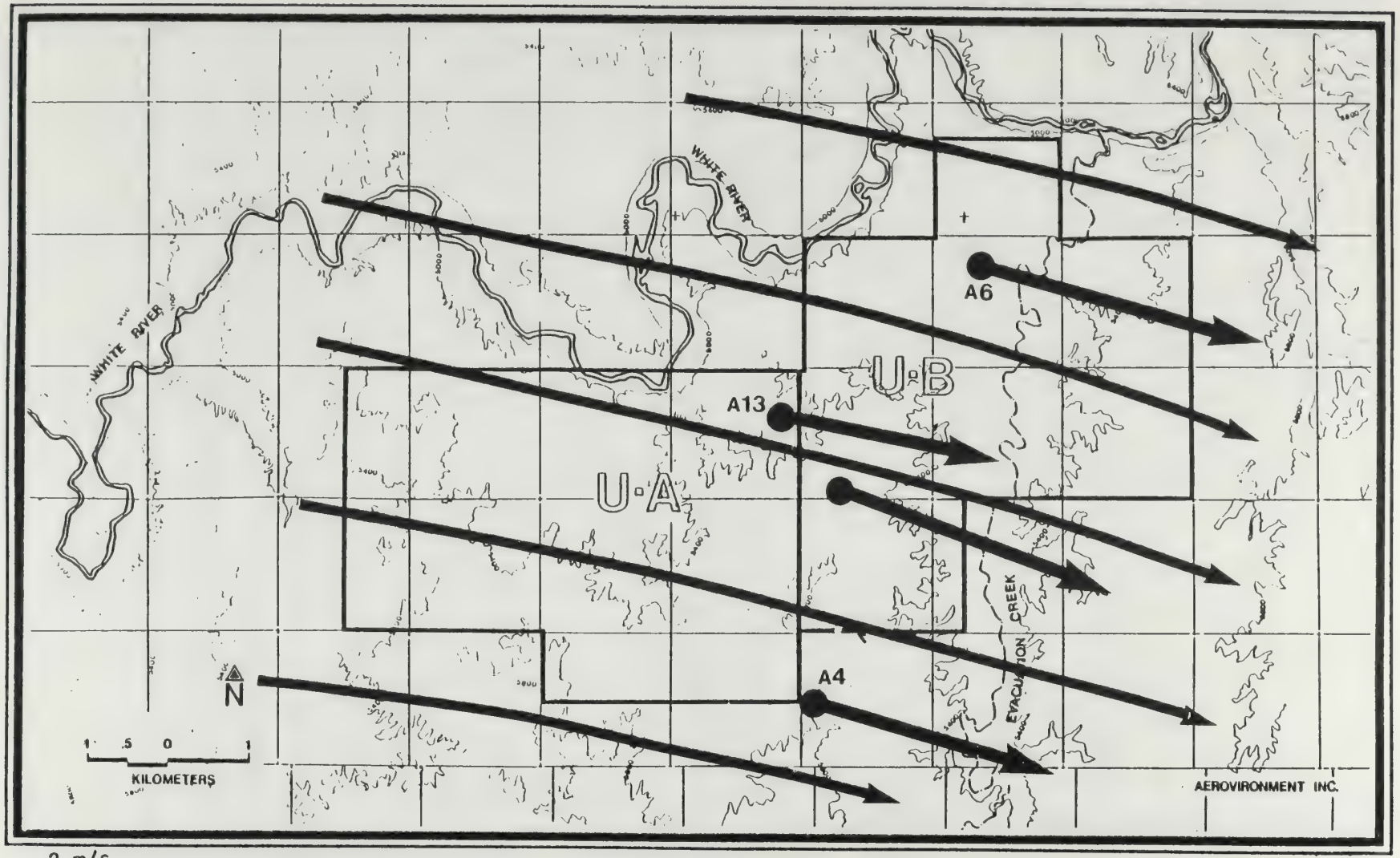


FIGURE 4.2-11. Typical synoptic airflow pattern on Tracts Ua and Ub during the afternoon.

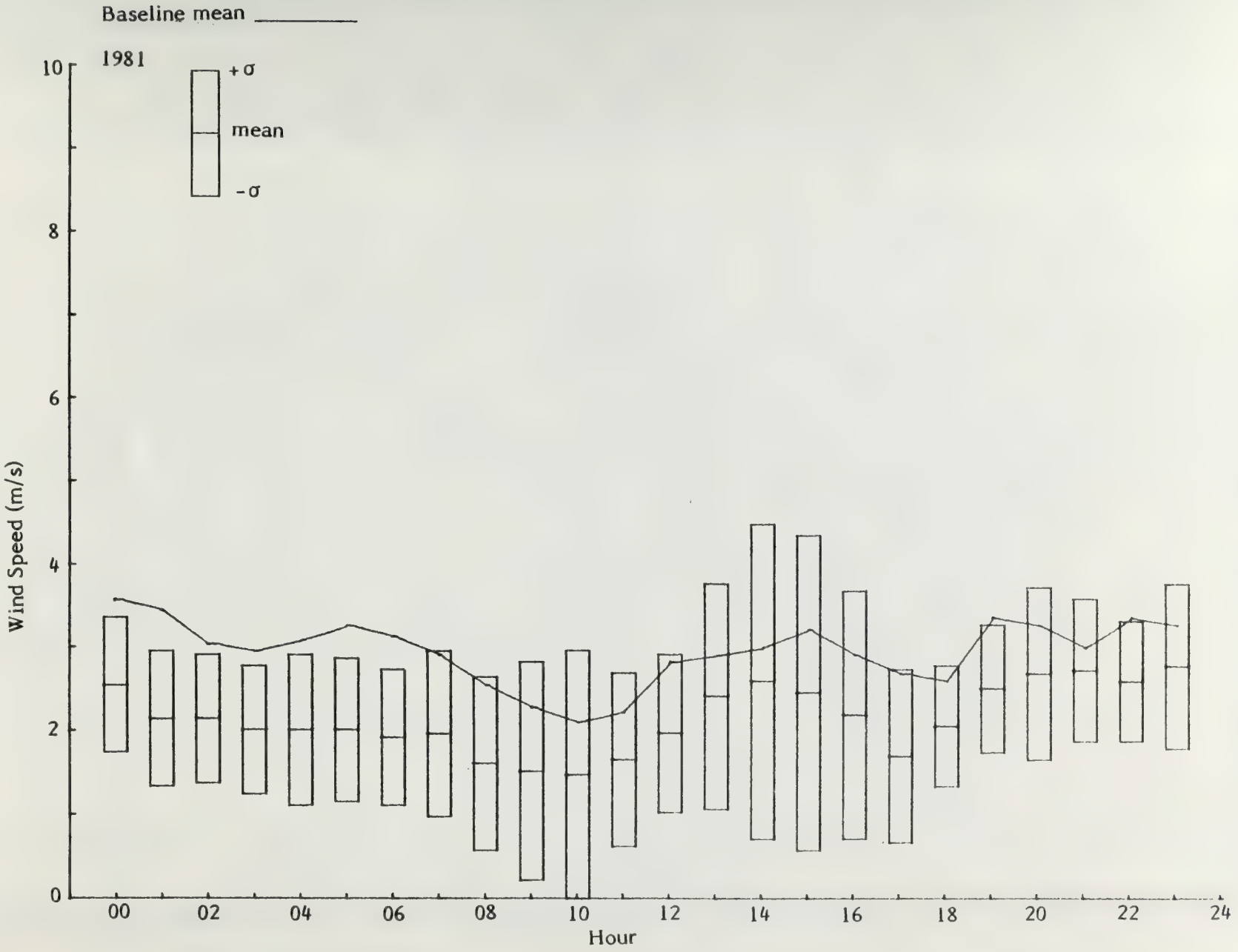


FIGURE 4.2-12. Diurnal variation of mean wind speeds and their standard deviations during January 1981 compared to the baseline means at site A6.

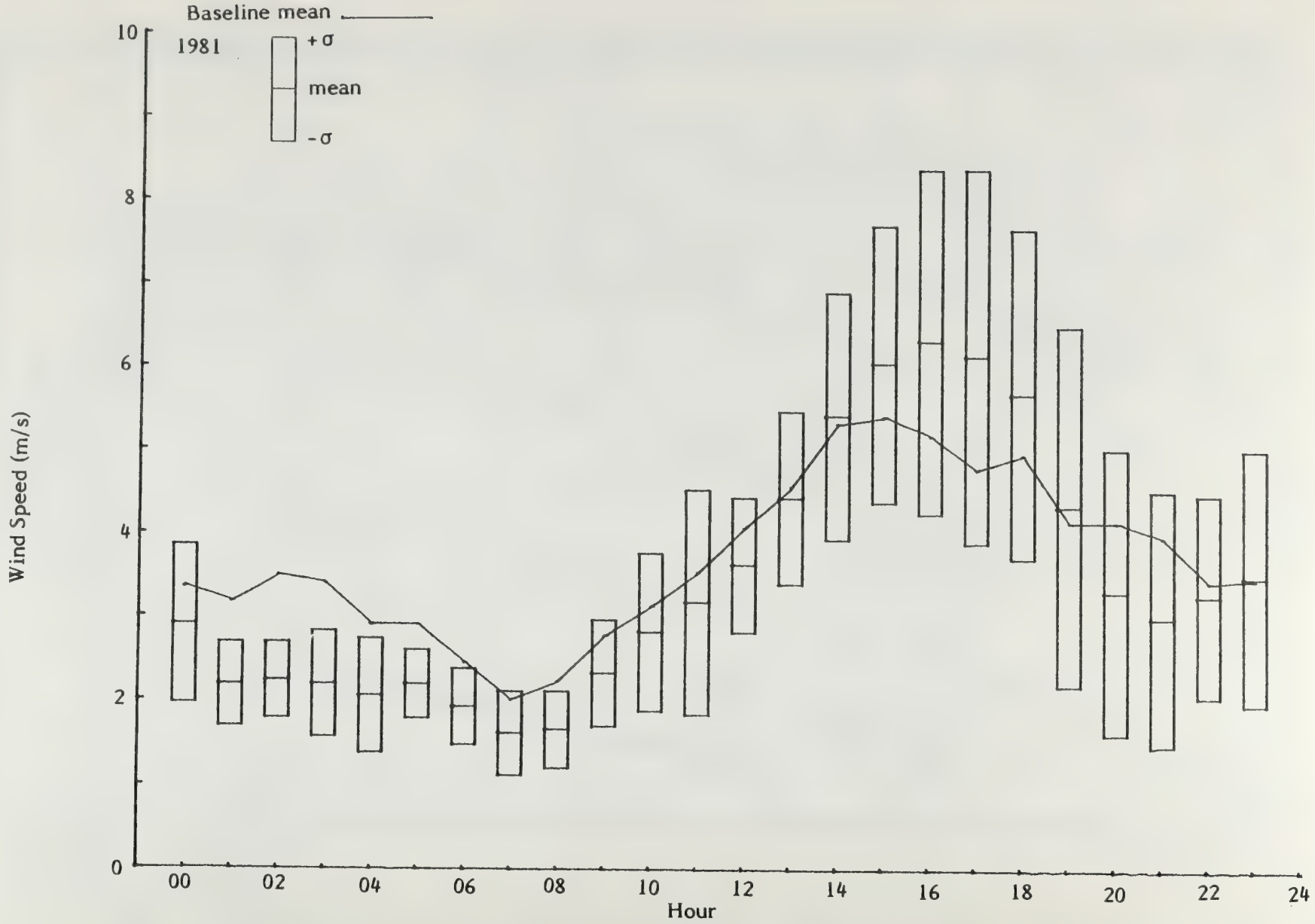


FIGURE 4.2-13. Diurnal variation of mean wind speeds and their standard deviations during July 1981 compared to the baseline means at site A6.

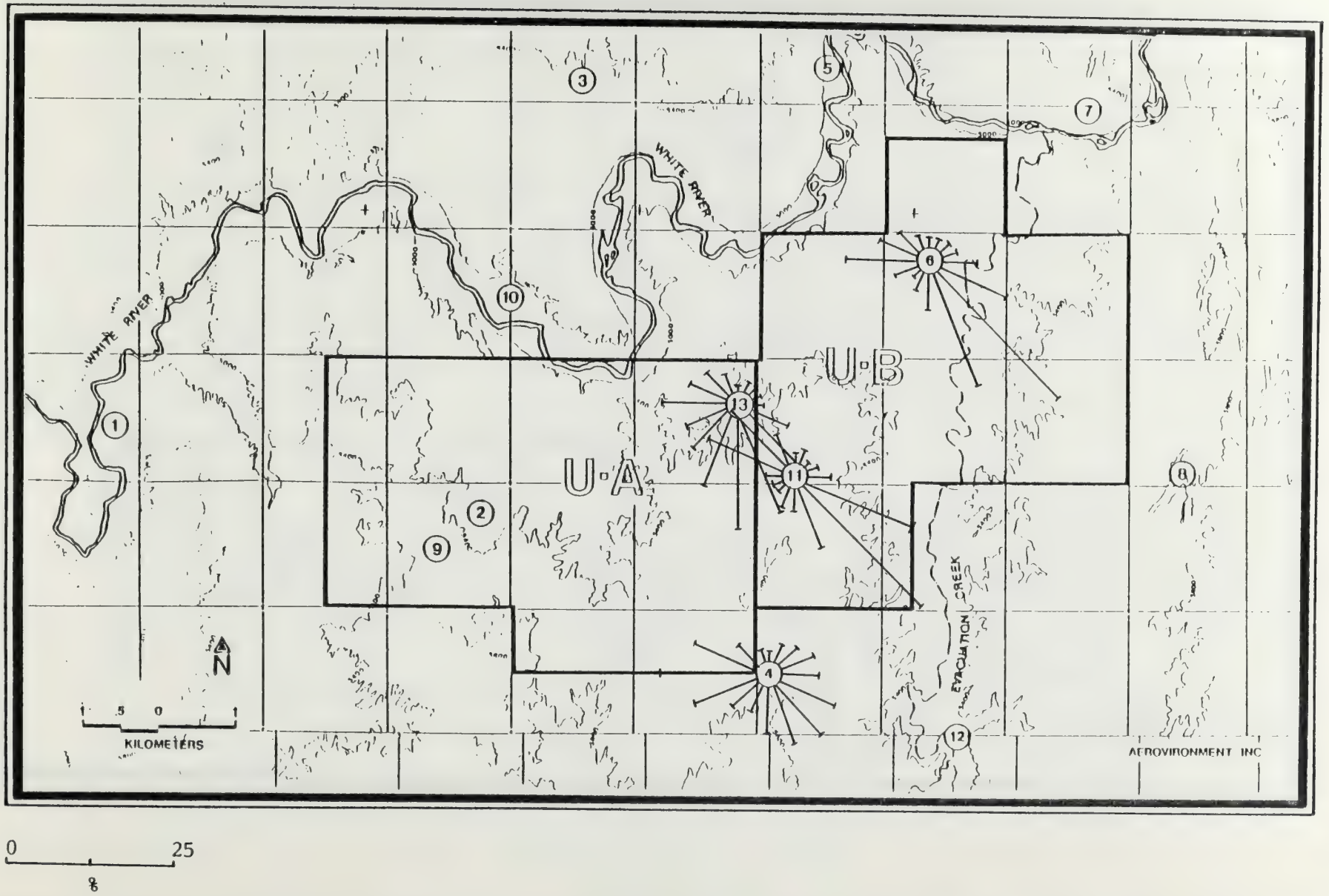


FIGURE 4.2-14. Directional wind roses at the monitoring stations on the Tracts for January 1981. The length of each bar represents the frequency of winds from the direction towards which the bar points.

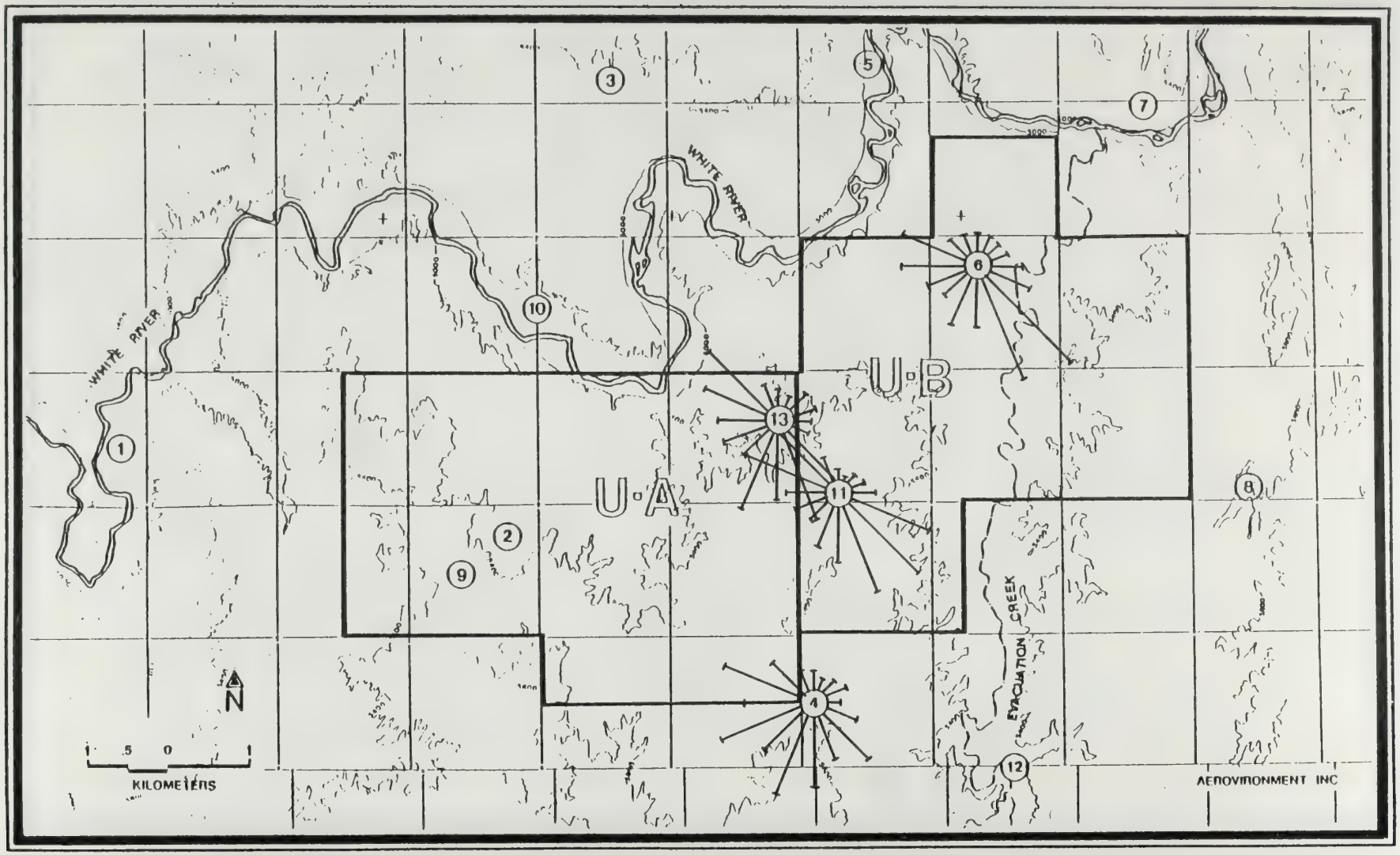


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FIGURE 4.2-15. Directional wind roses at the monitoring stations on the Tracts for April 1981. The length of each bar represents the frequency of winds from the direction towards which the bar points.

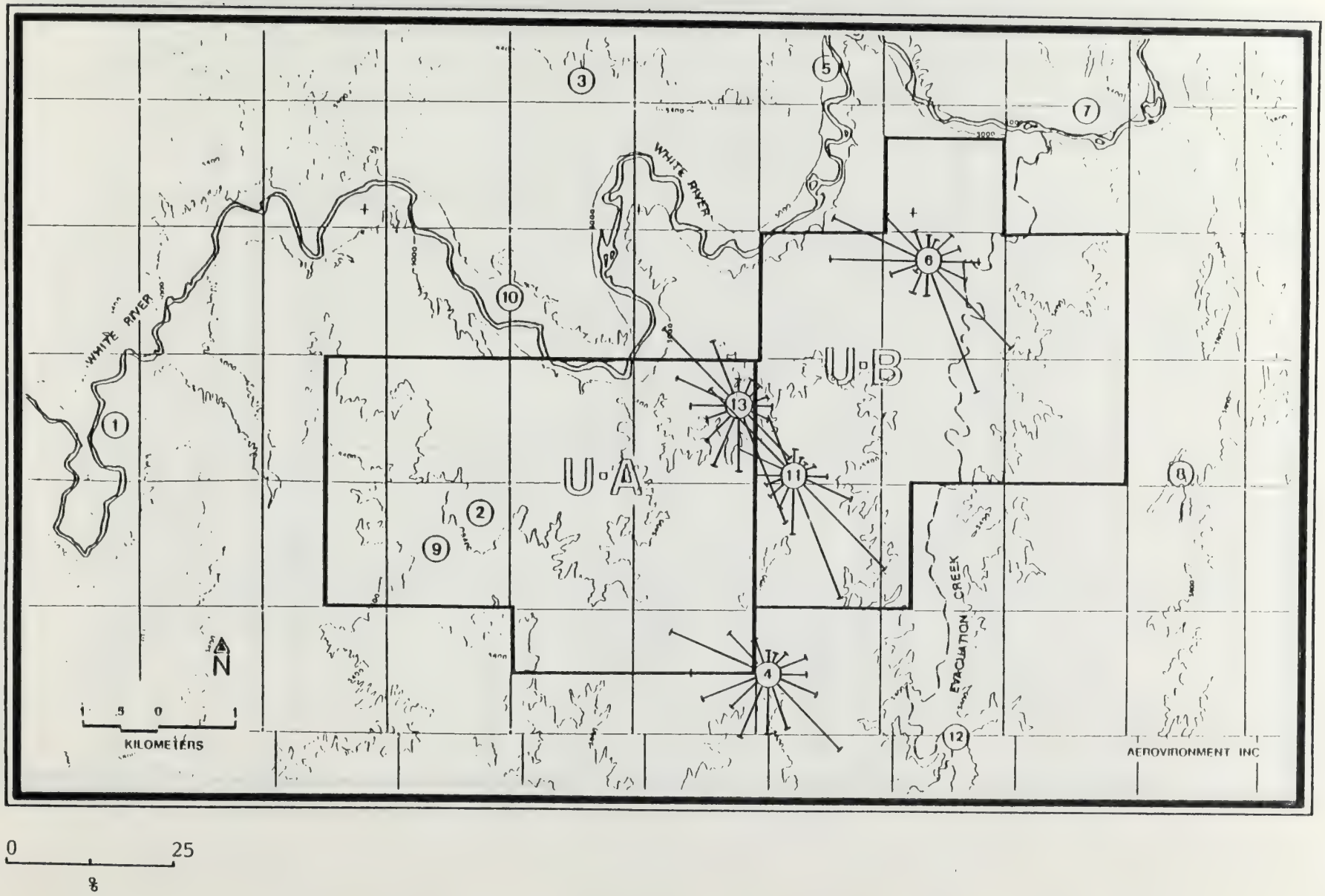

FIGURE 4.2-16. Directional wind roses at the monitoring stations on the Tracts for July 1981. The length of each bar represents the frequency of winds from the direction towards which the bar points.

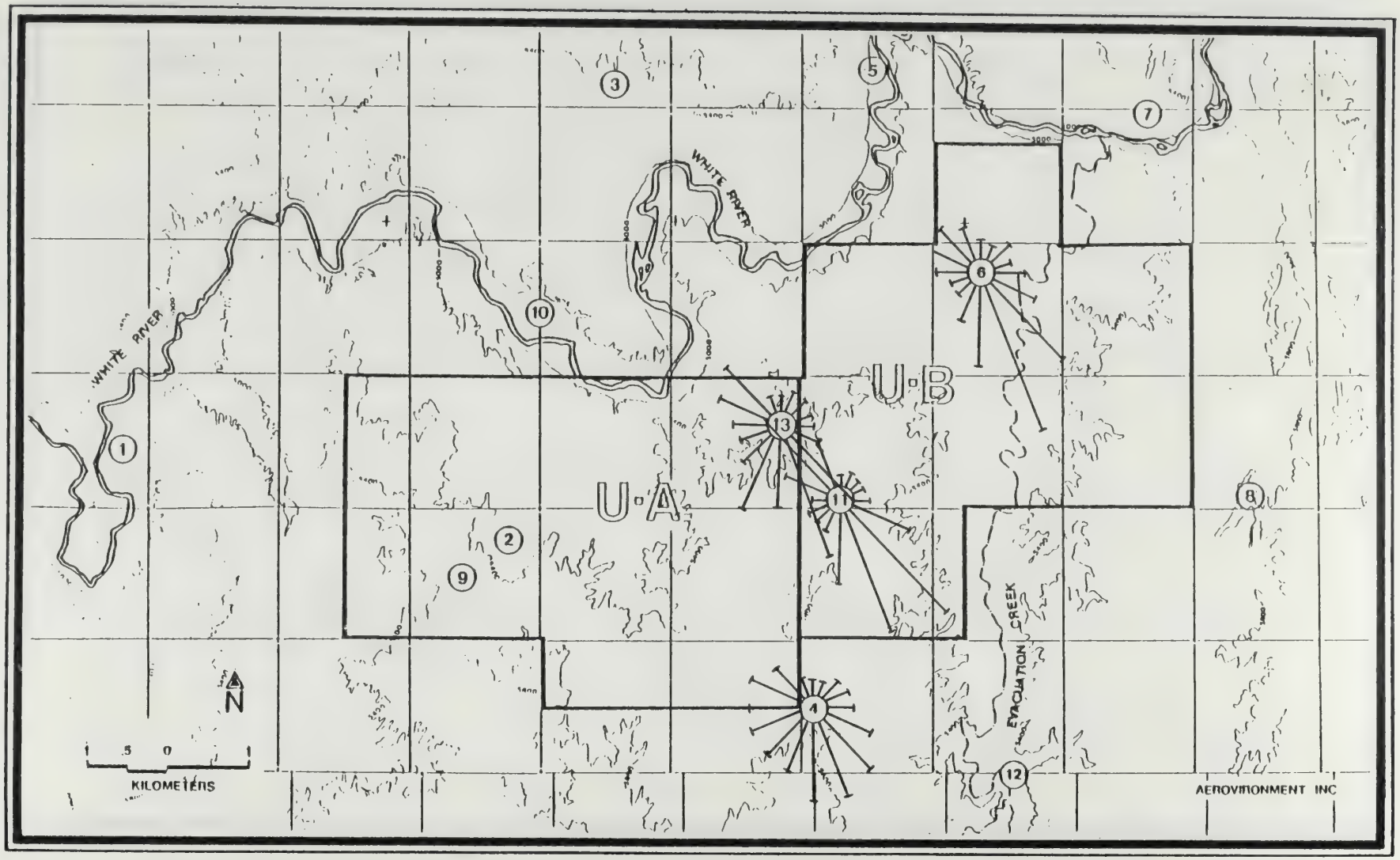

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FIGURE 4.2- 17. Directional wind roses at the monitoring stations on the Tracts for October 1981. The length of each bar represents the frequency of winds from the direction towards which the bar points.

baseline and interim periods. The frequent occurrence of this wind direction is a direct result of the drainage flow at Site A6.

Temperature

Figure 4.2-18 shows the diurnal variation in temperature and standard deviation for January and July 1981 at Site A11. (Data at Site A11 was used because data at Site A6 were not available during the month of July.) Superimposed on this for comparison are the average baseline values. The daily maximum temperature was generally observed between 1400 and 1600 MST, while the daily minimum was observed between 0400 and 0700 MST. The average temperatures are -6^{o} C for January 1981 and 22^{o} C for July 1981. These are shown on Figure 4.2-19 along with the maximum, mean and minimum for each month in 1981 as compared to the maximum, mean and minimum for the baseline period. During the entire monitoring period, the highest July temperature observed was 36^{o} C during July 1976 and August 1979 at Site A6; the lowest temperature observed was -30^{o} C during January 1979.

Relative Humidity

The diurnal variation of relative humidity is approximately the reciprocal of temperature, indicating that the amount of moisture in the air remains fairly constant during the day on the tracts. Figures 4.2-20 and 4.2-21 show the diurnal trend of the average and standard deviations for a winter month (January) and summer month

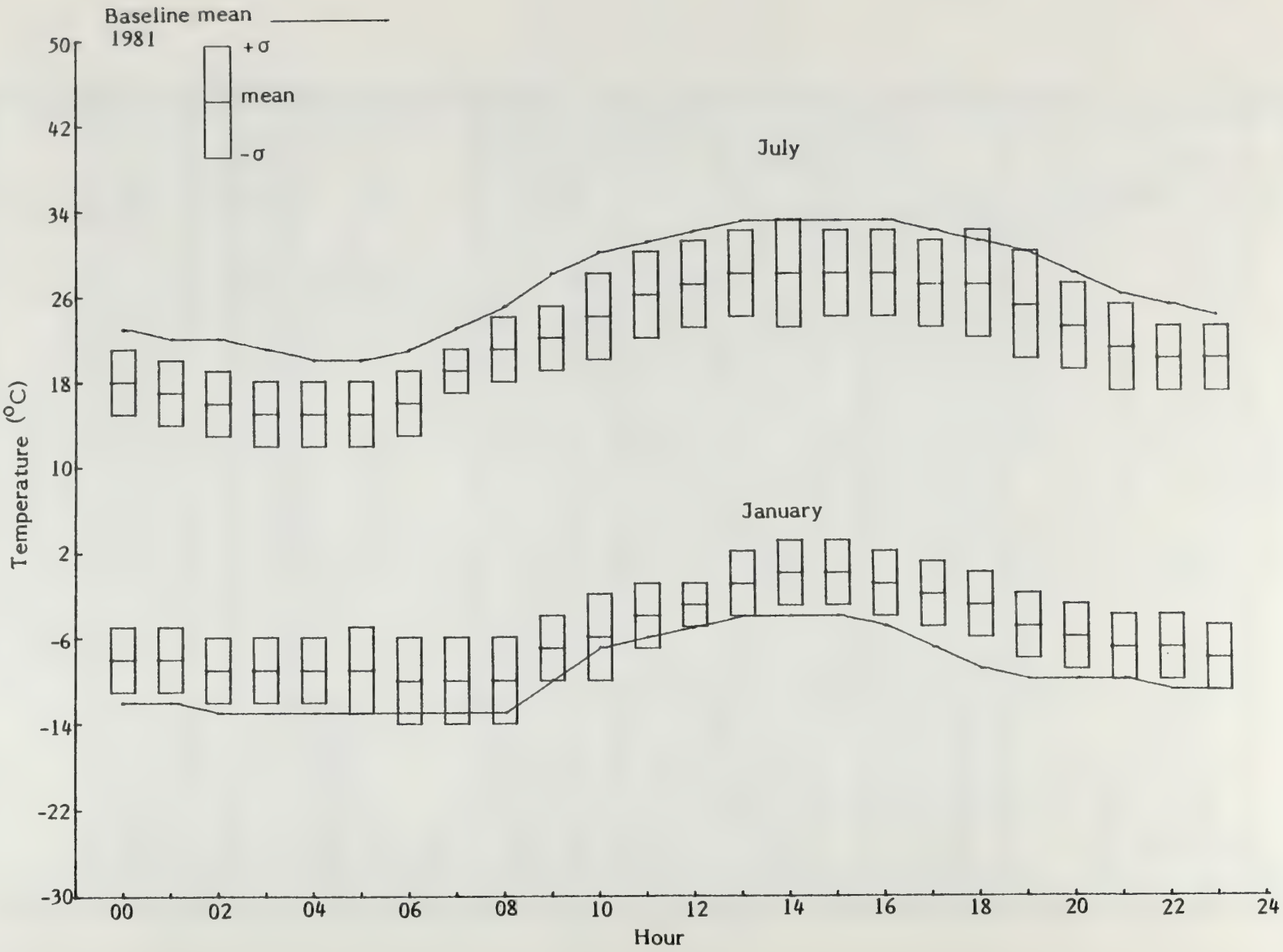

FIGURE 4.2-18. Diurnal variation of mean temperatures and their standard deviations compared to baseline means at site A11 during January and July 1981.

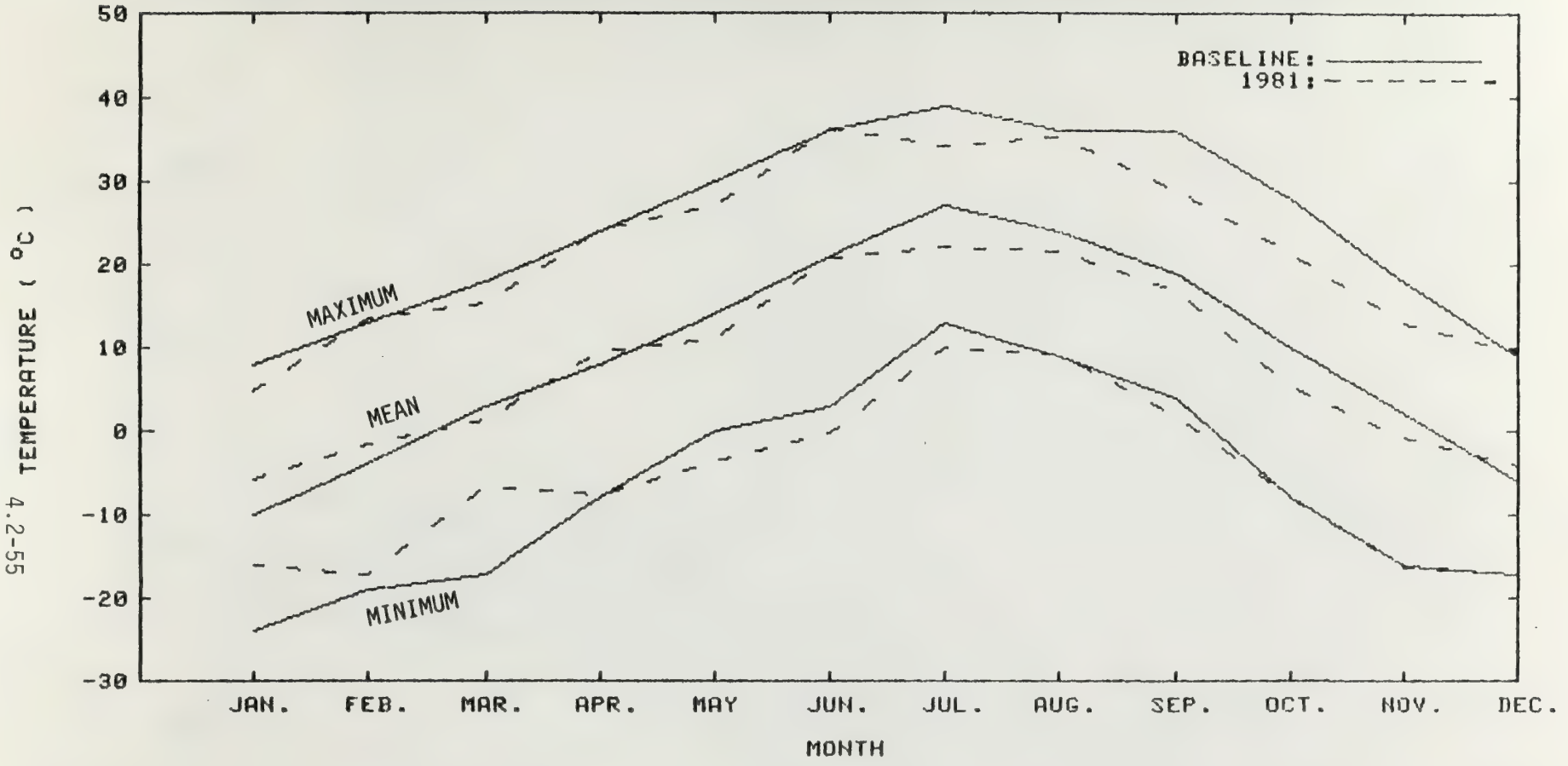

FIGURE 4.2-19. Monthly maximum, mean, and minimum temperatures at site A11 during 1981 compared to baseline.

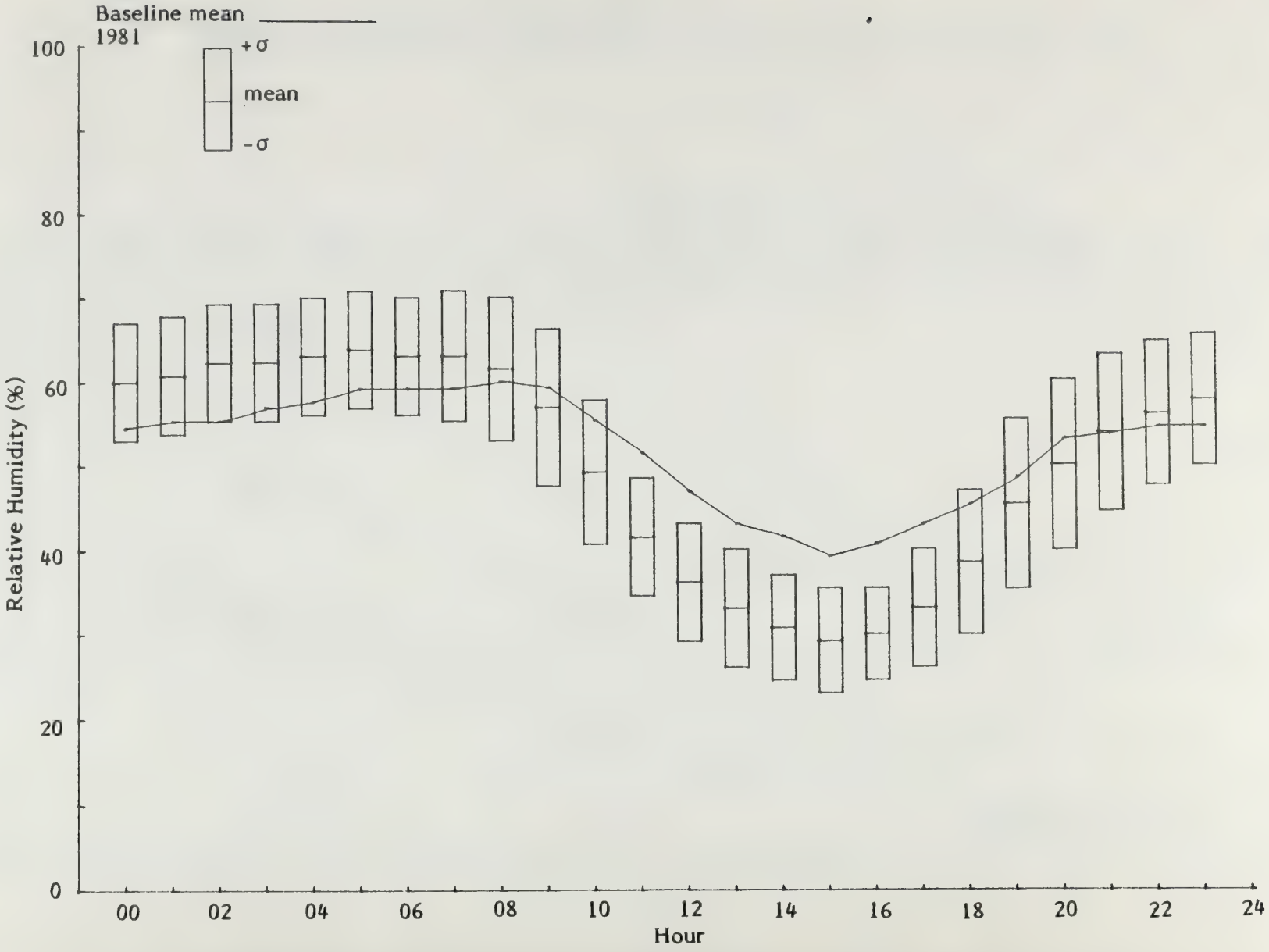

FIGURE 4.2-20. Diurnal variations of mean relative humidity readings and their standard deviations compared to the baseline means at site A6 during January 1981

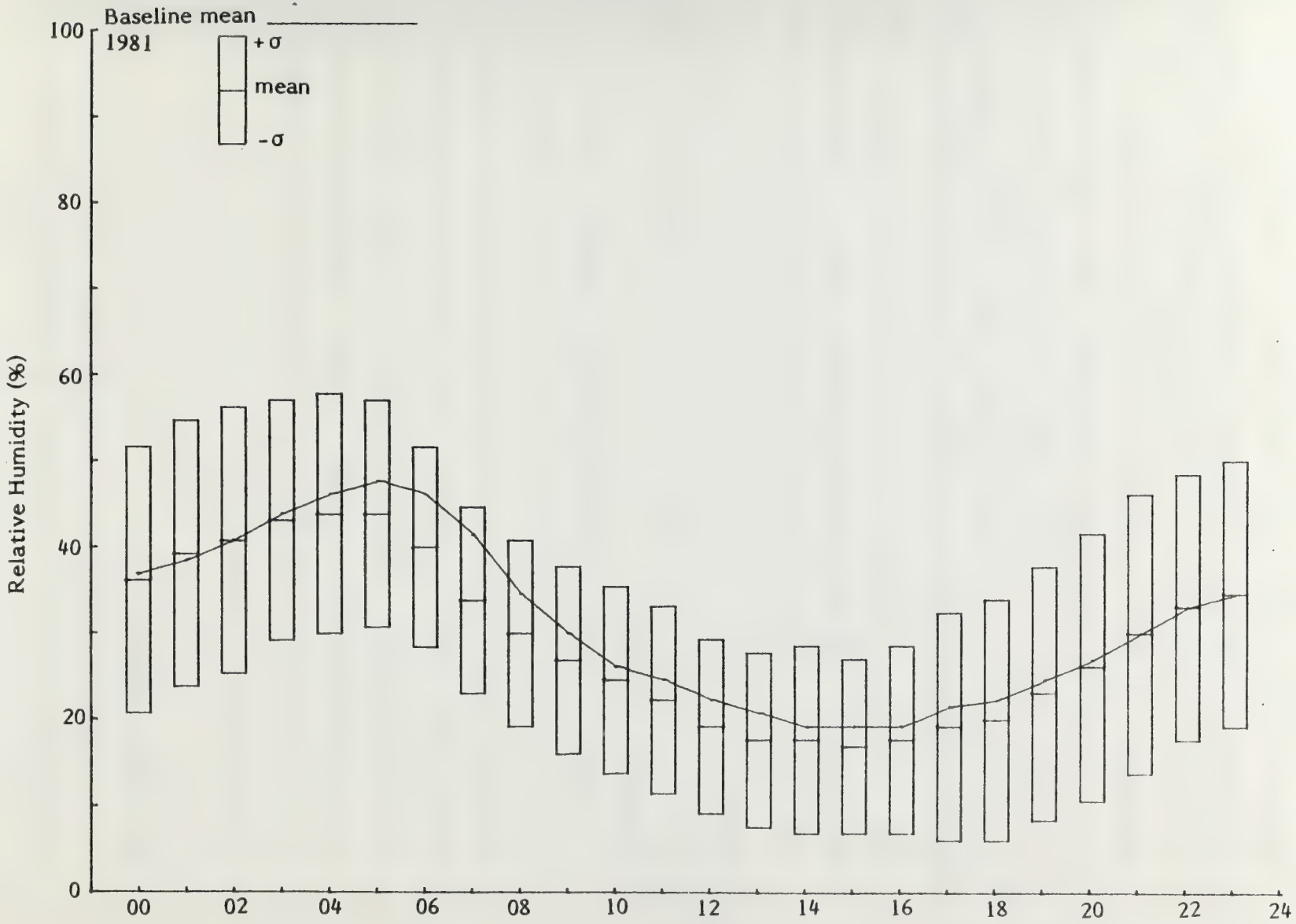

FIGURE 4.2-21. Diurnal variation of mean relative humidity readings and their standard deviations compared to the baseline means at site A6 during July 1981.

(July) at Site A6. The lack of storminess of January 1981 and the persistence of warm dry high pressure is reflected by the low relative humidity values compared to the baseline period. The relative humidity in July 1981 was comparable to the baseline average. The air is drier in summer than in the winter. The highest average readings are found in winter from 0400 through 0800 MST. The lowest values are found during summer afternoons between 1400 and 1600 MST. Table 4.2-18 shows the seasonal distribution of relative humidity at 0500, 1100, 1700, and 2300 hours for Site A6. These correspond to the reporting times of the National Weather Service. On an annual basis, relative humidity in 1981 was comparable to the baseline average.

Barometric Pressure

Figure 4.2-22 gives the mean monthly barometric pressure as well as the maximum and minimum monthly barometric pressure at Site A6 for 1981. The highest value observed was 644 mm of Hg during November 1981, and the lowest value was 617 mm of Hg during February, March, and May 1981. The winter storms cause the lowest readings and the basin highs bring the highest readings. During the summer the air mass systems are much weaker and, consequently, not much change in the pressure is evident.

Net Thermal Radiation

Figure 4.2-23 shows the average hourly net thermal radiation at Site A6 during January and July 1981. As expected, the radiation is

TABLE 4.2-18. Seasonal relative humidity (in %) at Site A6 for 1981 compared to the baseline average.

Season	Hour							
	0500		1100		1700		2300	
	Baseline	1981	Baseline	1981	Baseline	1981	Baseline	1981
Winter	83	81	65	48	55	44	77	73
Spring	72	68	45	38	37	32	62	54
Summer	58	55	39	32	25	27	42	42
Fall	65	74	39	47	32	43	53	63
Annual	70	70	45	41	37	37	59	58

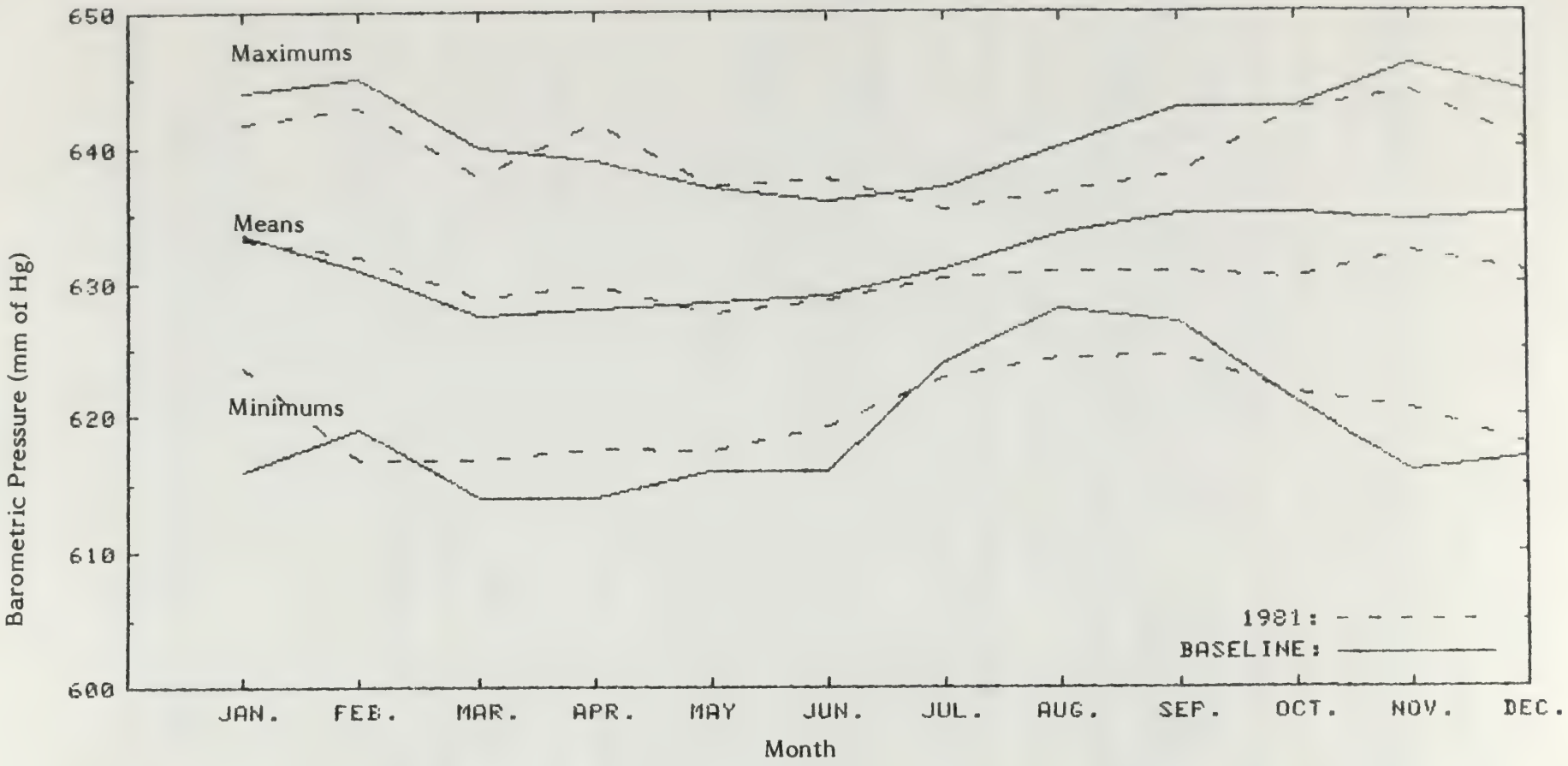

FIGURE 4.2-22. Monthly maximums, means, and minimums of the barometric pressure at site A6 during 1981 compared to baseline.

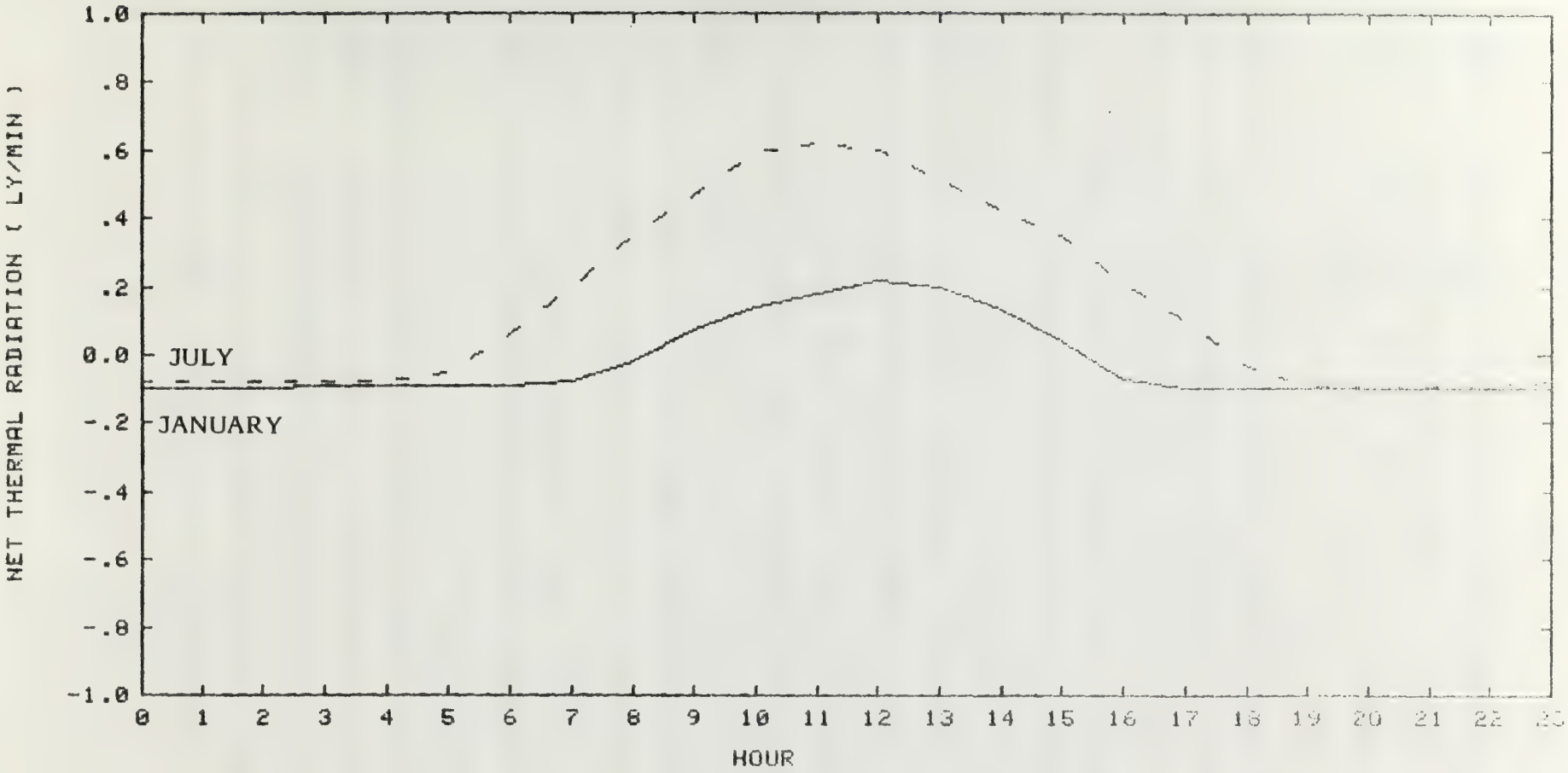

FIGURE 4.2-23. Diurnal variation of mean net thermal radiation at site A6 during January and July 1981.

higher in the summer due to the longer days, more intense sunlight, and less cloudiness. Highest values during the day generally occurred around noon.

4.2.2.4 Diffusivity. When a gaseous pollutant in the form of a plume or puff is released into the atmosphere it is transported by the prevailing wind. As it travels downwind its concentration decreases as its volume increases. Its growth in the vertical is governed mainly by the atmospheric stability, while its growth in the horizontal depends not only upon stability but on mechanical turbulence. Mechanical turbulence is defined as irregular airflow induced by surface roughness. A surrogate of mechanical turbulence is the fluctation of wind direction or sigma theta.

Using σ_θ data from Site A6, the frequency distribution of different "stability" ("diffusion") classes is computed in Table 4.2-19. The classification scheme used follows that in the Atomic Energy Safety Guide 23 (AEC, 1972) and appears in Table 4.2-20.

When the entire year is considered, stability Classes D and E are the most prevalent and the unstable classes (A, B, and C) account for 32% of the values.

A complete dispersion picture must also include the effect of plume rise. The meteorological parameters that greatly influence the height of a plume are vertical atmospheric (thermal) stability and wind speed. Vertical atmospheric stability can be best defined by ΔT data. In equations derived by Briggs (1974) for calculating

TABLE 4.2-19. Relative frequency distribution (%) of stability classes using σ_θ at Site A6 during 1981. Table 4.2-6 defines the classes A through G.

Season	Stability Classes							Total Number of Observations
	A	B	C	D	E	F	G	
Winter	6.3	6.8	14.6	31.6	32.3	4.1	0.1	2073
Spring	8.4	10.1	15.2	32.9	30.7	2.7	0.1	2179
Summer	6.1	14.0	18.6	29.2	29.2	2.9	0.0	2120
Fall	2.9	7.3	15.8	34.2	33.7	6.1	0.1	2145
All Year	5.9	9.6	16.1	32.0	32.3	4.1	0.1	8517

TABLE 4.2- 20. Classification of atmospheric stability using σ_θ.

Stability Classification	Pasquill Categories	σ_θ* (degrees)
Extremely unstable	A	25.0
Moderately unstable	B	20.0
Slightly unstable	C	15.0
Neutral	D	10.0
Slightly stable	E	5.0
Moderately or very stable	F	2.5
Extremely stable	G	1.7

Source: Atomic Energy Safety Guide 23 (AEC, 1972)

*Standard deviation of horizontal wind direction fluctuation over a period of 15 minutes to one hour. The values shown are averages for each stability classification.

plume height, only three atmospheric stability classes are needed. The classification scheme is listed in Table 4.2-21.

Figures 4.2-24 and 4.2-25 show the diurnal variation of ΔT collected at Site A6 for two months, January (winter) and June (summer) 1981. (July data was not available.) Because of the general cloudiness in January, the development of strong nocturnal stability was prohibited. Therefore, there was only a small diurnal variation in the mean ΔT and the stability was almost always slightly stable or neutral throughout the entire day. Very stable or slightly stable atmospheric conditions prevailed in early morning and evening during June. In the afternoon, neutral or unstable conditions were a general rule.

The frequency distribution of stabilities for each season based on ΔT appears in Table 4.2-22. This table shows that very stable conditions occurred more often during fall and winter. Unstable or neutral activities occurred equally throughout the entire year. The instrument for 1981 measures ΔT to within $\pm 0.1^{o}C/20$ meters over the measurement interval. Accuracy was below this level in the baseline period; hence, no comparison of the ΔT data is attempted.

Examining the entire set of joint frequency distributions, one finds the combination of very stable atmosphere ($\Delta T > 1.5^{o}C/100$ m), with low wind speeds (< 3.5 m/s) occurred 27% of the time during 1981, with such occurrences most frequent 36% in the winter and fall. Table 4.2-23 shows the relative frequencies of such occurrences by seasons for 1981.

TABLE 4.2-21. T stability scheme.

Stability	ΔT ($^{o}C/100m$)
1. Unstable and Neutral	<-0.5
2. Slightly Stable	-0.5 to 1.5
3. Very Stable	>1.5

Source: Briggs, 1974

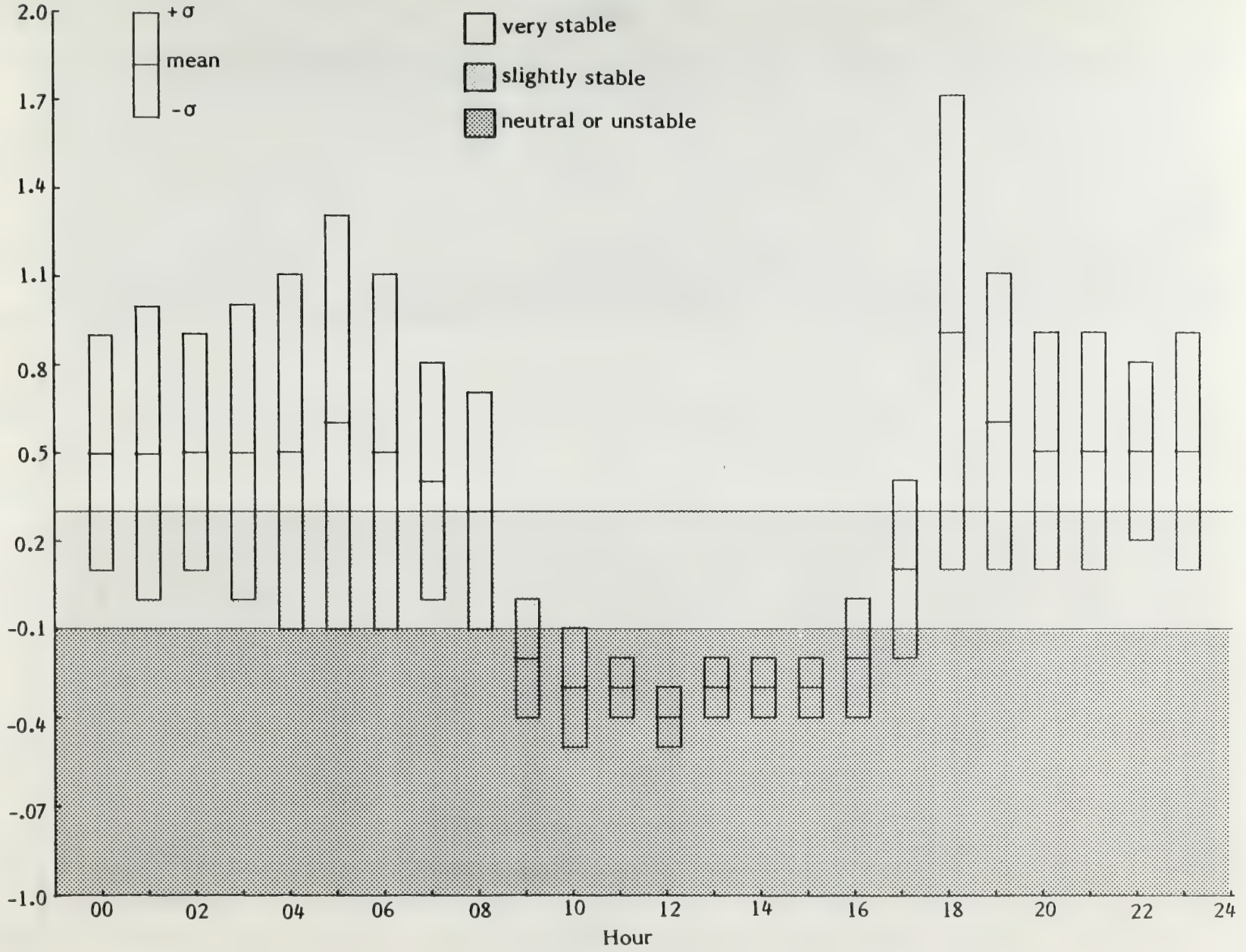

FIGURE 4.2-24. Diurnal variations of the mean ΔT and their standard deviations at site A6 during January 1981.

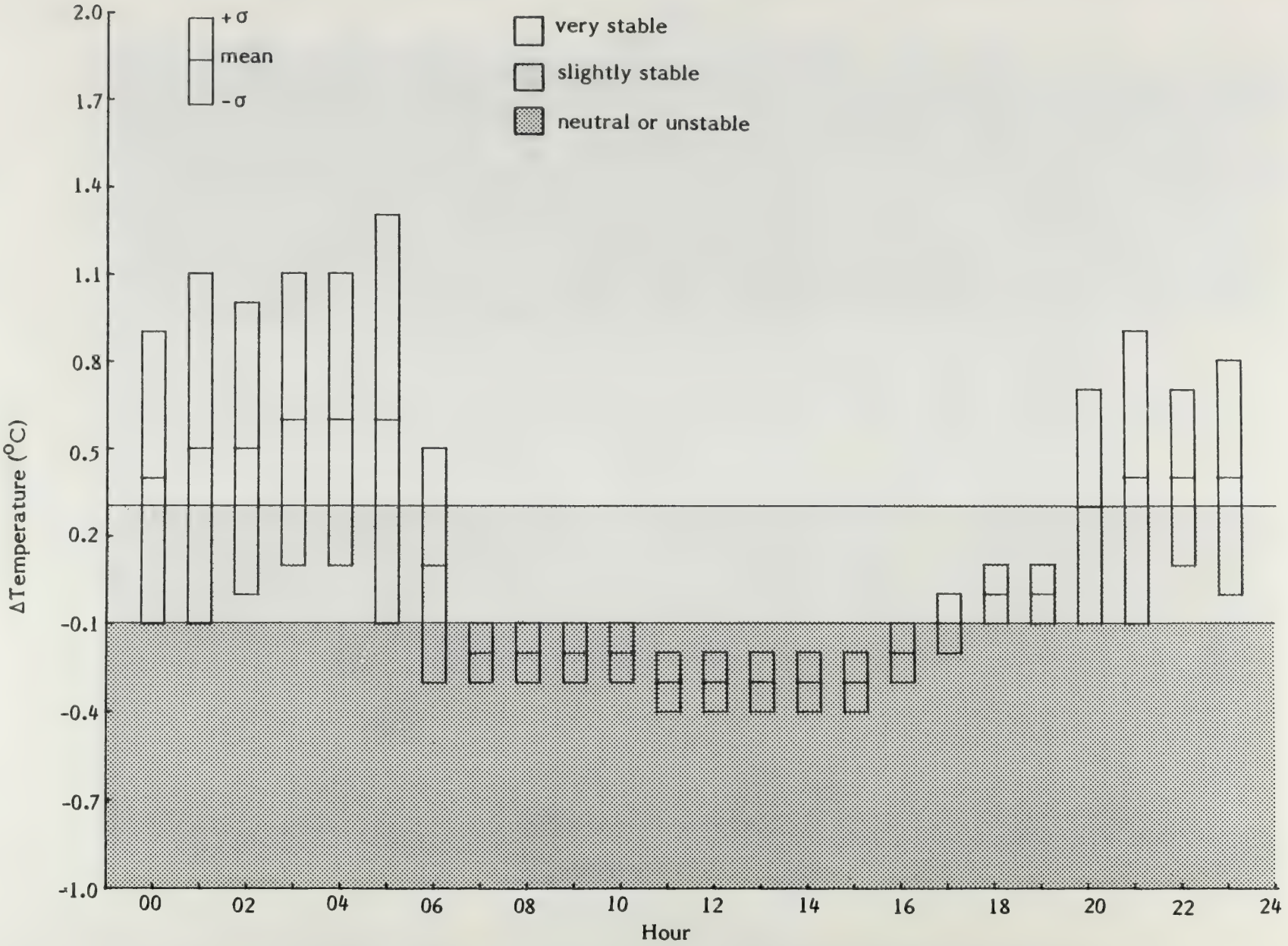

FIGURE 4.2-25. Diurnal variations of the mean ΔT and their standard deviations at site A6 during June 1981.

TABLE 4.2-22. Relative frequency distribution (%) of ΔT at Site A6 for 1981.

Season	Stablility (ΔT in $^{o}C/100m$)			
	Unstable or Neutral (<-0.5)	Slightly Stable (-0.5 to 1.5)	Very Stable (>1.5)	Total Number of Observations
Winter	39	22	39	2163
Spring	56	27	17	2217
Summer	48	27	25	620
Fall	33	29	38	986
All Year	45	26	29	5986

TABLE 4.2-23. Relative frequency (%) of low wind speed (3.5 m/s) combined with very stable (1.5°C/100 m) atmosphere for each season in 1981 at Site A6.

Season	Frequency (%)	Total Observations
Winter	36.9	796
Spring	15.3	337
Summer	19.3	122
Fall	36.4	359
All Year	27.0	1614

4.2.3 Sound Levels

Sound level measurements were made in quarterly surveys during the baseline data collection period. The measurements showed, as expected, that the Ua and Ub area sound levels were low (24-26 dB(A) with no wind at sites away from the Shite River) and uniform from season to season. Noise sources were primarily natural (e.g., insects, running water, rustling grass, wind). Background levels near the White River ranged from approximately 30 dB(A) to 60 dB(A) in moderate wind.

These measurements were resumed in October 1981 to update the baseline sound levels before construction begins. The equipment used was a Gruel & Kjaer type 2225 integrating sound level meter. Locations of sound level measurements in 1981 are shown in Figure 4.2-26. The typical background noise levels in 1981 were between 20-30 dB(A) and the highest value was 47 dB(A).

The background (natural) noise levels measured are very dependent upon winds. Water running in the White River is a more localized source of natural noise. Areas closer to these sources are correspondingly more noisy. On the tracts, man-made noises add to the natural background. Along roads the increase is greater, as expected. Vehicles account for the highest sound level measurements.

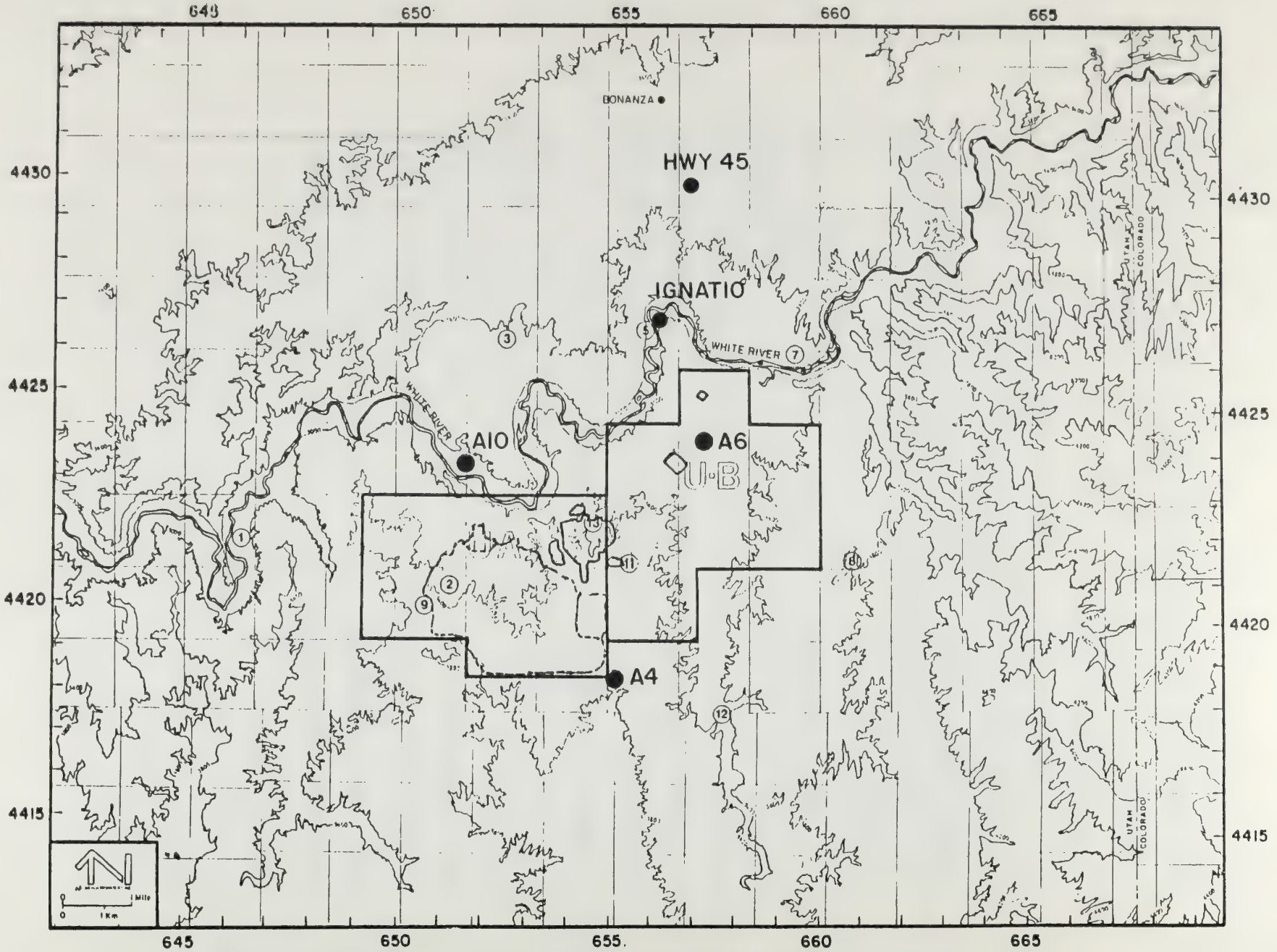

FIGURE 4.2-26. Sound level measuring sites.

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VEGETATION RESOURCES

4.3 VEGETATION RESOURCES

The following section discusses the vegetation monitoring studies conducted during 1981 by Native Plants, Inc. under contract to WRSP. The vegetation program, under the direction of Dr. Cyrus McKell, is divided into two catagories. The first is a continuation of the baseline monitoring studies initiated in 1975 to characterize vegetation resources and trends on the Utah tracts. The second is a continuation of reclamation research studies initiated both on the oil shale tracts, at a study site north of the tracts (Section 6), and at Anvil Points, Colorado.

4.3.1 Objectives

The major objectives of the vegetation resources monitoring program are to maintain the continuity of data collection on key environmental parameters, identify and quantify environmental trends, develop vegetation resource data to support the interpretation of terrestrial wildlife monitoring data, and to explore control/treatment methods for long-term monitoring. This effort is undertaken in compliance with lease terms and has as its major purpose the identification of project related impacts and the evaluation of the project's success in controlling adverse development related impacts.

In addition to monitoring existing tract conditions, reclamation research also was conducted to provide data on processed shale characteristics relevant to its reclamation, to describe the physical and chemical decomposition of processed shale, to determine plant tolerance and

response to processed shale characteristics, to assess the suitability of various plant materials for reclamation of both disturbed areas and processed shale, to develop plant establishment methods, and to measure topsoil response to long-term storage. The basic philosophy of the WRSP reclamation program will be to utilize natural processes and materials and to minimize the requirements for scarce resources such as water and topsoil.

4.3.2 Methods

The methods used in the 1981 studies have been generally described in previous progress reports. For studies initiated in 1981, specific methods will be described in the appropriate section of the report. The WRSP Environmental Monitoring Manual will also detail the methods employed.

4.3.3 Vegetation Monitoring Studies

In addition to the annual plant biomass measurements and sagebrush leader growth studies, in 1981 five new areas of vegetation monitoring were implemented to provide additional information about baseline conditions prior to project development. The five areas include; plant uptake of elements, litterfall measurements, assessment of annual use of plants by animals, a cryptogamic crust and lichen study, and a soil microbiology study.

The program to monitor prevailing vegetation continued to use the areas of sampling established in 1975 with the addition of several new areas necessitated by the addition of the new studies. The locations of

all the study areas are shown in Figure 4.3-1 and will be discussed more completely under each section in the data summary.

4.3.3.1 Production of Annual Plant Biomass Annual plant biomass is measured by harvesting the standing biomass of annual plants from a given soil surface area. Biomass of annual plants is an important source of herbage and seeds for animal feed and the resulting litter also serves to protect the soil from erosion and helps develop and maintain soil physical and chemical conditions.

Cheatgrass (Bromus tectorum) tended to be in patches according to favorable soil moisture. Later summer growth of Russian thistle (Salsola kali) and halogeton (Halogeton glomeratus) was benefited by moderate later summer precipitation. An upswing in rabbit populations during 1981 appeared to be related to increased plant biomass in 1980.

In June 1981, five productivity study areas were visited in each of the four major vegetation types identified during the baseline program. In each study area, aboveground annual plant biomass was harvested from twenty 0.25 m^2 plots. Plants were measured for height, clipped at ground level, and returned to the lab for analysis. Notes on vegetation conditions were recorded relative to plant density and the randomness of plant production in the more favorable growth sites. Estimates of plant production and plant cover were recorded.

Despite a fairly wet spring, the production of annual biomass was lower than most of the other years sampled. The results of the 1981 production data are summarized and comparisons are made with previous years in Table 4.3-1. Again, the riparian had the largest values for

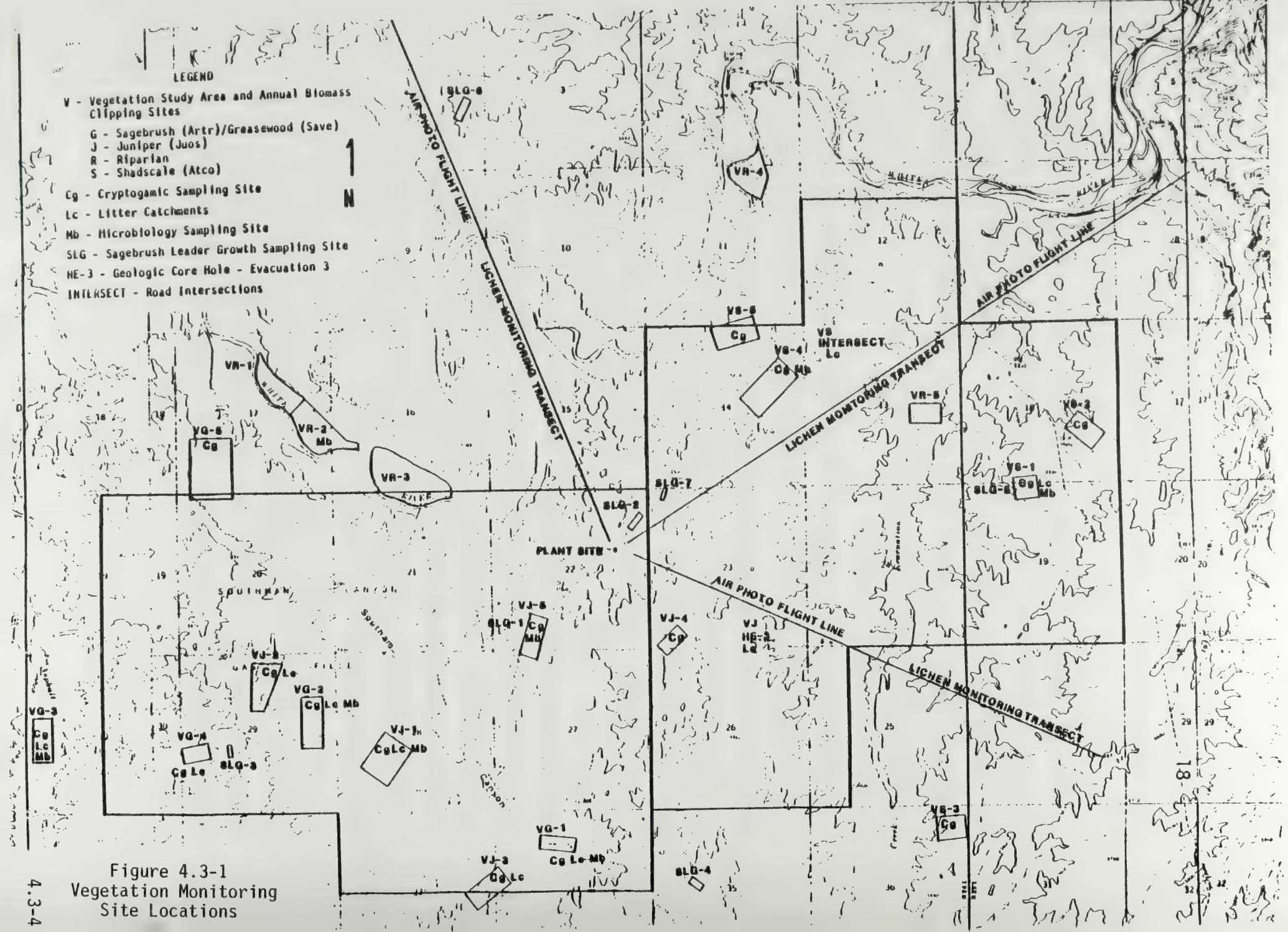


Figure 4.3-1
Vegetation Monitoring
Site Locations

Table 4.3-1. Biomass production of annual understory vegetation of four primary vegetation types during 1981 and compared with previous years.

Sample Location(1)	VEGETATION TYPE							
	Shadscale		Sagebrush-Greasewood		Juniper		Riparian	
	Production (gm/m^2)	Plant Cover (%)	Production (gm/m^2)	Plant Cover (%)	Production (gm/m^2)	Plant Cover (%)	Production (gm/m^2)	Plant Cover (%)
1	7.2	2.0	29.6	11.0	1.2	0.4	29.2	8
2	16.4	6.0	15.6	4.0	0.4	0.2	167.6	40
3	2.4	1.0	30.8	7.0	0.8	0.3	33.2	31
4	9.2	3.0	2.0	1.0	0.4	0.1	4.4	2
5	10.8	5.0	1.2	1.0	0.4	0.1	23.2	6
1981 Avg.	9.2	3.4	15.8	4.8	0.6	0.2	51.5	17.4
1980 Avg.	21.8	2.3	8.9	0.9	0.5	trace	(3)	(3)
1979 Avg.	16.5		16.9		6.3		82.5	
1978 Avg.	5.4		35.1		1.6		80.0	
1977 Avg.	(2)		(2)		(2)		(2)	
1976 Avg.	3.8		20.9		0.3		30.6	
1975 Avg.	224.3		51.1		3.8		590.0	

(1) Each value is a mean of 10 plots within areas sampled during and since the Baseline.

(2) Vegetation was not sampled (too meager to harvest).

(3) Biomass sampling data unavailable because of sample handling problem.

production and cover of the four vegetation types considered averaging 51.5 gm/m^2 and 17.4% respectively. The juniper type had the lowest figures averaging 0.6 gm/m^2 for production and 0.2% for cover. There remains a very strong relationship between spring precipitation and annual biomass. Production values for individual vegetation types are discussed below.

A. Shadscale Vegetation Type Annual species were rather low for this vegetation type in 1981. Cheatgrass was the dominant annual species on this vegetation type and it occurred most frequently in protected areas underneath shrubs. Cover estimates averaged 4% with a range from 1% to 6%.

B. Sagebrush - Greasewood Vegetation Type Annual species production in the sagebrush-greasewood areas averaged nearly twice that of 1980. However, the total is still low in comparison to 1975 or 1978 production values. Average production was 15.8 gm/m^2 (156 kg/ha). The general pattern of plant distribution was similar to the shadscale type with most of the production occurring underneath the shrubs and open areas between shrubs being essentially bare of annual plants. Besides cheatgrass, and annual Cryptantha sp. and pepperweed (Lepidium perfoliatum) were occasionally found within this vegetation type. Cover values for the annual species were considerably higher than 1980. The 1981 cover averaged 4.8% with a range of 1% to 11%.

C. Juniper Vegetation Type The production of annual species in this vegetation type was very low as is typical with the juniper zone. Average production was only 0.6 gm/m^2 compared with 0.5 gm/m^2 in 1980. The dominant annual species in this type was cheatgrass with some

lambs' quarters (Chenopodium album) and pepperweed. The total cover in the juniper sites sampled averaged 0.2% cover which is similar to 1980 data.

D. Riparian Vegetation Type As in all previous years, the riparian vegetation type produced the most annual plant biomass. Again, the dominant annual species was cheatgrass, with a fair abundance of yellow sweetclover (Melilotus officinalis), pepperweed, and fat hen saltbush (Atriplex patula). The grazing pressure on the riparian areas is more severe than on the other vegetation types and much of this disturbance leads to an increase in the preponderance of annuals. These annuals may in turn serve as a source of food for animals during a short period in the spring. The production of annuals for 1981 averaged 51.5 gm/m^2. Average cover values for the riparian vegetation sites ranged from 2% to 40% with an average cover of 17%.

4.3.3.2 Sagebrush Stem Growth Sagebrush (Artemisia Tridentata) leader growth is a linear measurement of the current year's twig/stem growth measured from the previous year's bud scale scars to the end of leaves at the tip of current growth. This parameter is not a direct expression of plant biomass or volume of growth, but instead is an index of plant vigor, production, and general response to environmental conditions. Numerous ecologists have observed, and data gathered by WRSOC consultants on the tracts demonstrate, that sagebrush leader growth appears to reflect the general environmental conditions controlling growth (McArthur et al., 1978; Baker, 1981).

Sagebrush leader growth was chosen because of its ease of measurement, the widespread distribution of sagebrush in Tracts Ua and Ub, and

the value of growth as an index of perennial plant function throughout the entire year. This index of shrub vigor is a key character of a dominant plant species on the oil shale tracts. Significant reductions in sagebrush leader growth would signal a serious and impending consequence to wildlife species depending on the perennial vegetation for their food and cover. Sagebrush leader growth has been and is currently being compared with other shrub leader growth and appears to be representative of those species studied.

There was no change during 1981 in methodology for the sagebrush stem growth measurements. The annual growth of 20 stems on each of 20 separate plants in each of six sampling locations (2400 samples) was measured. During 1981 one additional site (SLG-7) was included in the program as a contingency prior to site development. Each measurement was from the bud-scale scar of the previous year to the tip of the new growth.

Growing conditions for sagebrush in 1981 were suboptimal for all seven monitoring sites. This is generally reflected also in the reduced plant production of annuals and other perennial plants occurring on the tracts. The decrease in stem length is apparently highly correlated with fall-winter precipitation. The precipitation for the fall-winter period averaged only 2.98 inches which was the lowest average since the drought of 1977. The stem length was correspondingly the smallest since 1977.

Average stem length ranged from 2.2 cm at site SLG-5 on the east edge of the tract to 3.9 cm at Site SLG-7 which is a newly established site just east of site SLG-2. Table 4.3-2 summarizes the results of 1981 stem leader growth. The standard deviations for all seven sites are

Plant No.	Site 1 Stem Length Avg.	Site 1 SD	Site 2 Stem Length Avg.	Site 2 SD	Site 3 Stem Length Avg.	Site 3 SD	Site 4 Stem Length Avg.	Site 4 SD	Site 5 Stem Length Avg.	Site 5 SD	Site 6 Stem Length Avg.	Site 6 SD	Site 7 Stem Length Avg.	Site 7 SD
1	3.2	1.1	4.3	2.0	3.6	1.3	2.9	1.1	2.4	0.7	3.5	1.0	2.9	0.8
2	2.3	0.8	4.5	1.5	3.0	1.0	2.2	0.5	1.5	0.2	1.9	0.5	3.0	0.6
3	3.2	1.7	4.1	1.2	3.1	1.3	2.3	0.5	2.0	0.5	2.6	0.7	4.3	1.3
4	2.7	0.7	3.1	0.8	3.5	0.9	3.5	1.1	1.8	0.4	2.6	1.0	4.6	1.1
5	3.4	1.0	3.7	1.1	2.8	0.7	2.1	0.5	2.2	0.8	1.9	0.4	3.5	0.9
6	1.6	0.4	2.8	1.1	2.4	0.5	3.6	0.9	2.6	0.7	2.2	0.6	3.0	0.7
7	3.1	0.9	3.0	0.7	3.2	0.8	2.5	0.4	3.7	1.3	2.1	0.4	4.6	1.3
8	2.9	0.9	2.4	0.5	3.2	1.0	2.7	0.7	2.0	0.5	3.6	1.2	2.8	0.7
9	4.7	1.7	3.4	0.9	3.2	1.2	3.4	1.0	2.1	0.7	2.9	0.6	4.2	1.4
10	2.8	0.6	2.4	0.8	4.3	1.3	2.8	0.8	2.0	0.5	2.4	0.6	3.9	0.8
11	2.0	0.6	3.7	1.0	2.7	0.9	3.5	0.8	2.2	0.5	2.3	0.4	3.6	0.9
12	2.1	0.4	3.3	0.9	2.9	1.0	3.3	2.1	2.6	0.8	2.8	0.8	3.2	0.6
13	2.2	0.5	2.6	0.7	4.2	1.4	3.1	0.6	1.7	0.4	2.8	0.9	3.7	1.1
14	1.7	0.7	2.9	0.9	2.5	0.6	2.0	0.4	2.0	0.4	3.4	1.4	4.9	1.9
15	2.3	0.7	3.5	1.1	2.7	0.6	2.6	0.8	1.4	0.2	2.8	0.9	4.7	1.4
16	2.0	0.7	2.2	0.6	2.5	0.7	2.4	0.5	2.0	0.7	2.9	0.7	3.8	1.0
17	2.5	0.5	3.5	0.9	2.7	0.9	3.0	0.8	3.0	0.7	3.3	1.1	3.4	0.8
18	3.4	1.0	4.1	1.1	4.0	1.0	2.4	0.5	2.4	1.1	3.3	0.9	5.2	1.6
19	3.3	1.0	3.5	1.0	2.5	0.4	2.7	0.6	2.1	0.6	2.6	0.6	4.9	1.4
20	3.8	0.7	2.9	0.7	3.8	1.1	2.7	0.8	2.1	0.7	3.1	0.7	3.3	0.8
Avg.	2.8		3.3		3.1		2.8		2.2		2.8		3.9	
SD	0.8		0.7		0.6		0.5		0.5		0.5		0.8	

Table 4.3-2. Average stem length (cm) as measured October 1981. Data are mean values from 20 stems per plant.

quite uniform which illustrates that the variability of stem growth is low. The low average stem length and the small standard deviation suggests that 1981 was a much harsher year for plant growth than would be expected from the annual precipitation values (see Table 4.1-19) and that the poor growing conditions were fairly uniform for all sites observed. Over the seven years of study, sagebrush stem growth has ranged from 2.7 cm in 1977 to a high of 8.4 cm in 1979 (Table 4.3-3). The average 1981 sagebrush leader growth (3.0 cm) was very near the low of 2.7 cm in 1977. Sagebrush leader growth appears to provide a realistic index of the year-to-year variability that occurs within the oil shale tracts and provides a good monitoring device to estimate plant variability within the ecosystem.

In addition to the leader growth measures for sagebrush, measurements for three other species, fourwing saltbush (Atriplex canescens), Utah juniper (Juniperus osteosperma), and greasewood (Sarcobatus vermiculatus) were sampled in 1981. These species were sampled from only Site SLG-7. Sample size was dependent on the number of individuals of each species in the sites. Seventy-four individuals were sampled for fourwing saltbush, 44 for Utah juniper, and 93 for greasewood. The largest two non-inflorescence leaders were measured for each plant giving a total of 14, 88, and 186 samples for the three species, respectively.

Average leader growth was 14.0cm$\pm$ 6.3, for fourwing saltbush, 3.4cm$\pm$ 1.0 for Utah juniper, and 3.3cm$\pm$ 1.9 for greasewood (Table 4.3-4). The juniper and greasewood measures are very close to the averages for sagebrush while the fourwing saltbush had considerably more growth than the other three species. These species will be

Table 4.3-3. A comparison of sagebrush stem growth over a seven-year period, 1975 to 1981, on sites related to prototype oil shale tracts Ua and Ub.(1) Values are expressed in centimeters.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Average
1975								
Mean	7.4	6.9	9.7	5.6	7.1	5.4		7.0
SD	2.14	1.12	1.86	1.03	1.31	1.5		
1976								
Mean	6.2	6.16	7.0	5.5	5.4	4.8		5.9
SD	1.04	1.63	0.88	1.06	1.17	1.08		
1977								
Mean	2.1	2.0	4.0	2.2	2.8	2.8		2.7
SD	0.35	0.25	1.02	0.25	0.59	0.56		
1978								
Mean	8.4	8.1	10.1	6.4	5.6	6.5		7.5
SD	1.76	2.88	2.16	1.10	1.59	2.52		
1979								
Mean	7.6	9.9	9.9	8.2	7.3	7.7		8.4
SD	2.0	2.2	2.5	2.1	1.8	1.9		
1980								
Mean	4.6	6.4	7.5	4.8	3.9	3.6		5.1
SD	1.4	1.9	1.7	1.3	1.1	1.0		
1981								
Mean	2.8	3.3	3.1	2.8	2.2	2.8	3.9	3.0
SD	0.8	0.7	0.6	0.5	0.5	0.5	0.8	

(1) Each value is the mean length of 20 stems on 20 plants (i.e., 400 observations/site/year).

Table 4.3-4. Leader growth measurements of fourwing saltbush, Utah juniper, and greasewood from Site SLG-7. Measures represent the two longest non-inflorescence leaders per branch.

Fourwing saltbush Leader Growth					
15.0	14.0	17.0	13.7	17.2	14.6
13.2	12.2	12.6	11.5	15.0	5.4
12.0	12.0	11.2	15.3	28.0	7.5
10.9	8.4	11.2	12.4	12.0	7.9
8.2	16.5	14.7	26.7	14.5	11.5
7.6	14.0	13.5	5.2	10.5	11.0
12.3	16.2	22.5	4.2	22.7	13.2
7.0	12.5	21.0	22.0	13.7	12.5
14.5	16.2	22.2	22.0	33.5	
8.0	11.2	21.0	13.4	--	
8.5	17.2	13.9	25.5	12.0	
5.7	5.3	13.0	12.4	11.0	
14.0	16.1	26.0	27.0	15.4	
14.0	11.2	7.4	25.5	15.3	
16.0	19.0	13.0	10.0	17.3	
12.0	16.2	7.5	6.0	16.9	
14.3	13.2	13.0	10.9	44.5	
9.3	8.0	10.5	10.6	34.6	
8.4	14.4	13.7	19.0	22.5	
7.7	12.3	15.3	16.5	26.0	
12.9	11.2	15.7	12.5	20.8	
8.6	10.9	14.8	11.0	17.8	
9.5	8.8	15.5	5.0	10.5	
9.0	3.2	15.0	2.5	8.5	
16.4	20.0	16.0	14.0	7.2	
14.2	11.8	15.6	7.0	5.0	
8.1	20.1	11.0	16.5	20.0	
9.0	12.7	11.0	10.0	18.6	

$\bar{X}$ 14.0

SD 6.3

No. of plants sampled - 74

Utah juniper Leader Growth			
4.0	3.0	2.6	3.7
4.7	3.2	3.5	3.7
3.8	4.4	4.2	3.4
4.5	1.8	2.1	2.7
3.5	3.1	4.8	
5.2	3.5	2.6	
2.5	4.0	2.4	
4.9	3.8	2.0	
3.5	3.3	1.5	
4.0	1.1	2.1	
4.0	3.3	3.5	
5.0	3.5	2.3	
3.7	3.0	4.0	
4.5	3.5	2.7	
4.5	3.2	2.0	
4.7	3.0	2.0	
3.2	2.3	4.5	
4.1	4.0	4.4	
4.5	2.5	5.5	
5.0	4.5	2.7	
2.5	3.5	4.5	
4.0	3.5	4.0	
1.7	1.1	3.5	
3.0	3.0	4.4	
3.1	2.7	4.5	
3.5	4.8	3.5	
2.0	3.7	2.8	
3.6	2.0	2.3	

$\bar{X}$ 3.4

SD 1.0

No. of plants sampled - 88

Greasewood Leader Growth						
2.8	3.4	2.3	2.1	3.7	3.7	3.0
2.7	3.0	2.1	2.0	3.1	3.4	2.7
2.3	4.3	3.5	2.5	3.4	3.6	2.5
2.1	4.2	1.6	2.5	2.9	2.4	1.8
2.1	4.7	7.0	8.3	3.7	5.1	3.0
1.2	3.6	2.0	7.0	3.4	5.0	2.0
2.6	3.0	1.6	6.4	2.1	2.1	2.6
1.9	2.2	0.5	5.5	1.9	2.1	2.5
7.0	1.5	5.7	5.0	3.8	4.1	2.1
5.0	1.1	5.2	3.7	3.5	2.9	1.6
5.0	3.0	0.8	5.5	5.3	3.5	3.5
2.5	1.5	0.3	4.4	5.2	3.0	2.0
7.0	1.5	1.6	5.5	4.0	2.0	2.0
2.3	1.0	1.5	5.0	3.3	1.6	1.4
5.7	10.0	6.8	5.5	3.2	2.5	2.4
4.6	8.0	6.2	5.4	2.6	2.0	1.3
4.5	4.0	5.3	5.2	10.0	3.0	1.7
2.0	3.7	4.5	2.5	5.5	1.7	1.3
1.5	3.0	2.3	1.4	1.7	3.3	
1.2	2.5	1.0	1.2	1.2	1.8	
3.3	2.5	2.0	2.5	8.5	2.1	
2.1	2.3	1.7	2.3	6.3	1.7	
4.6	2.5	3.4	3.0	3.6	3.5	
2.5	2.0	2.6	1.5	3.0	3.5	
3.1	10.7	1.9	3.5	6.7	4.3	
0.7	5.7	1.3	2.6	4.1	3.2	
3.0	6.5	6.5	2.1	9.6	1.5	
2.7	2.0	6.0	1.7	7.5	1.4	

$\bar{X}$ 3.3

SD 1.9

No. of plants sampled - 186

*Site 7. Established at Sec. 14 and 23 near X-4 drill hole.

monitored again in 1982 so that their yearly responses can be compared to sagebrush. This will provide information as to the suitability of using sagebrush as a measure of general plant resources on the White River Shale tracts.

4.3.3.3 Elemental Content of Sagebrush Sagebrush leaders from the seven sagebrush leader growth sites were analyzed for elemental content of several potentially deleterious compounds. The parameters were analyzed to establish a baseline for future comparisons to assess effects of processing operations. Nine parameters (Mo, As, Na, Ca, Mg, SO_4, Hg, Cd, and B) were analyzed from the sagebrush tissue. The parameters were selected because they may increase in the plant tissue during processing operations and may accumulate to levels deleterious to the plants or its consumers (Kilkelly and Lindsay, 1979; OTA, 1980).

Values reported from the analyses are shown in Table 4.3-5 and represent composite samples of 12 leaders per site. All of the values obtained are within the normal range of concentrations within plants as reported by Gough et al. (1979).

The variance of the means for several of the parameters are fairly large and adequacy of sampling requirements have not been met. Sampling will be expanded in 1982 to insure statistical accuracy. The variance in tissues samples could be due to two principal factors: (1) natural variance among sites and individuals; and (2) variation in the analytical tests for the different elements sampled. The tests for Ca, Mg, Mg, SO_4 appear to be quite precise while those for As, Hg and Cd are somewhat more variable. Sampling will be expanded in 1982 to determine

Table 4.3-5 Elemental content of sagebrush (ARTR) leaders. Samples 1-7 are composite samples of 12 leaders from sites SLG Sites 1-7, respectively. Samples 8-11 are individual plant samples from SLG-2.

	Sample Number	Mo (PPM)	As (PPM)	Na %	Ca %	Mg (PPM)	SO_4 %	Hg (PPB)	Cd (PPB)	B (PPM)
1.	S1-C	0.83	0.3	0.275	0.490	870	0.18	15	12.5	40
2.	S2-C	0.70	0.4	0.486	0.445	930	0.23	9	14.8	26
3.	S3-C	1.0	0.2	0.535	0.430	760	0.17	<2	4.0	19
4.	S4-C	0.63	0.3	0.490	0.405	850	0.23	30	1.7	22
5.	S5-C	0.35	0.2	0.335	0.445	930	0.21	18	1.1	22
6.	S6-C	0.50	0.4	0.305	0.450	790	0.19	7	1.0	25
7.	S7-C	0.63	0.2	0.296	0.430	760	0.22	25	1.0	25
8.	S2-2	<0.10	1.0	0.096	0.495	800	0.15	50	0.7	24
9.	S2-5	<0.10	0.6	0.222	0.450	820	0.29	75	0.7	20
10.	S2-12	0.58	0.2	0.183	0.358	750	0.24	20	1.0	29
11.	S2-17	0.43	0.2	0.304	0.420	770	0.26	25	0.9	22
Total	$\bar{X}$	0.56	0.4	0.321	0.438	820	0.21	37	3.6	25
	s	0.24	0.3	0.136	0.038	66	0.04	20	5.1	6

where the variance is occurring (analytical testing or site to site) and to determine an adequate baseline for comparisons after the processing facilities are in operation and with plants grown in processed shale.

4.3.3.4 Litterfall Measurements The amount of litter returning to the soil is closely related to production of plant biomass for a given year. Litterfall is measured under the canopy of the dominant shrubs and juniper trees and may include the litterfall from shrubs and perennial forbs as well as the litter from annual species.

Measurements of litterfall are important because excess litterfall of leaves and twigs from shrubs and juniper may indicate undue stress on plants (excess litterfall has been observed in areas of high air pollution). Litterfall is also essential to the normal functioning of many soil parameters and to many small animals. The area around shrubs where the litter accumulates is the nutritional "storehouse" for arid plant communities (Garcia and McKell, 1970; Bjierregard, 1971) and any significant change in litterfall would result in changes in many ecosystem functions.

Litter traps were constructed in late spring and placed under the shrub species during the June sampling period. A total of 43 litter traps were placed, with each species (seven total) having 6 traps or replications. The seven species sampled were sagebrush, fourwing saltbush, shadscale (Atriplex confertifolia), Greenes rabbitbrush (Chrysothamnus greenii), hopsage (Grayia spinosa), Utah juniper, and greasewood. The litter traps were roughly triangular in shape with dimensions of 153 cm x 111 cm x 111 cm (Figure 4.3-2a). The sides of the

Figure 4.3-2a Generalized view of litter trap placement in relation to shrub canopy. Oil shale tracts Ua, Ub.

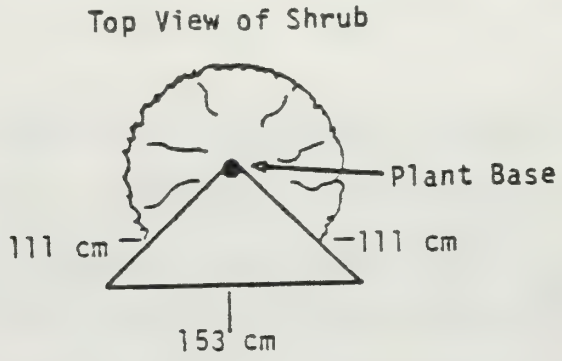


Figure 4.3-2b Litter trap placement.

traps were 16 cm in height to prevent litter from blowing out of the traps. The bottom of the traps consisted of 1/8 inch hardware cloth which is small enough to catch most of the litter fragments but will allow water to pass through and prevent decomposition. The typical placement of the litter traps is shown in Figure 4.3-2b. A size index for the plants was also calculated so adjustments or comparisons could be made in litterfall from small or large plants. The size index is computed by multiplying the height by the crown diameters (in two directions). This approximates a volume which can then be used to compare between differing sized individuals as well as between different sized species.

The litter traps were visited in October and the litter for that period (June-October) was removed, placed in bags and the traps replaced. The litter samples were taken to the lab, oven dried for 14 days at 25°C and then weighed. The results for the weights and size indices for each species are shown in Table 4.3-6. Utah juniper had the greatest litterfall for a five month period, however, the plants were also the largest. On a per cubic unit basis, greasewood produced the most litter and was followed by hopsage yielding equivalents of 347.3 g/m^3 and 115.6 g/m^3, respectively.

The size index was also compared with the litterfall for each of the species to determine if a relationship exists between plant size and litterfall. The results showed that variation between individuals was sufficiently large and the sample size was relatively small, consequently, no significant relationships could be determined. However, as would be expected, the trend was more litter from larger plants. Sample size will be increased in 1982 so that much of the variation may be reduced

Table 4.3-6. Summary of the litterfall and size index sampling.

Species	Litter-fall(gm)	Size Index(m^3)	Species	Litter-fall(gm)	Size Index(m^3)	Species	Litter fall(gm)	Size Index(m^3)	Species	Litter fall(gm)	Size Index(m^3)
ARTR 1	3.7	0.93	ATCA 1	1.7	0.35	ATCO 1	7.1	0.11	CHGR 1	2.3	0.23
ARTR 2	2.4	0.15	ATCO 2	24.3	1.01	ATCO 2	28.8	0.11	CHGR 2	0.7	0.49
ARTR 3	5.4	0.18	ATCA 3	29.3	3.46	ATCO 3	25.7	0.13	CHGR 3	2.8	0.22
ARTR 4	5.5	0.38	ATCA 4	29.1	0.84	ATCO 4	12.4	0.15	CHGR 4	2.9	0.43
ARTR 5	20.6	0.15	ATCA 5	20.7	0.29	ATCO 5	29.0	0.58	CHGR 5	2.4	0.27
ARTR 6	6.1	0.68	ATCA 6	5.0	0.70	ATCO 6	11.3	0.25	CHGR 6	1.0	0.18
$\bar{X}$	7.3	0.41		18.4	1.11		19.1	0.22		2.0	0.30

Species	Litter-fall(gm)	Size Index(m^3)	Species	Litter-fall(gm)	Size Index(m^3)	Species	Litter fall(gm)	Size Index(m^3)
GRSP 1	26.7	1.44	JUOS 1	55.9	5.09	SAVE 1	8.0	0.62
GRSP 2	6.7	0.59	JUOS 2	25.4	3.49	SAVE 2	2.0	1.17
GRSP 3	53.3	0.86	JUOS 3	43.6	3.29	SAVE 3	14.9	0.76
GRSP 4	13.3	0.27	JUOS 4	20.6	0.66	SAVE 4	13.4	0.24
GRSP 5	3.5	0.32	JUOS 5	80.0	2.98	SAVE 5	4.8	0.57
GRSP 6	3.8	0.26	JUOS 6	82.6	5.51	SAVE 6	6.9	0.91
			JUOS 7	62.8	7.71			
$\bar{X}$	17.9	0.62		61.8	4.10		8.3	0.71

and significant correlations may be possible. Also the traps will be placed under the total plant canope.

4.3.3.5 Assessment of Annual Use of Plants by Animals An assessment of the use of plants by animals was made during the October sampling period. Several sagebrush individuals were evaluated visually during this period and percentage of use was very low (<5%). Also, five other shrub species (fourwing saltbush, shadscale, greenes rabbitbrush, greasewood, and hopsage) were evaluated visually for current year grazing use. In all cases no species showed visual estimates of over 5% use which was the lowest possible category. Much of this was in response to a very dry year and lack of new growth on most species as discussed above.

Since this method was strictly qualitative, no statistical analyses are appropriate; however, sample size was felt to be very adequate. A more quantitative approach will be undertaken in the 1982 vegetation monitoring program (as outlined in the WRSP Environmental Monitoring Manual). This approach, which is based on Cole browse transects will provide a better and more defensible evaluation of plant utilization by wildlife and grazing animals.

4.3.3.6 Cryptogamic Crust and Lichen Study In arid and semi-arid regions of the world, the naturally low vegetal cover leaves a large percentage of land exposed. In regions where soils are gravelly, a "pavement" of pebbles protects the soil from the erosive forces of wind and water. Where the soils lack the desert pavement, another factor assumes an equally important role in checking erosion. A community of

non-vascular plants or "cryptogams" grow on or immediately beneath the surface of the soil. Where they are well established, the cryptogams form a recognizable crust.

Mosses, liches, and algae are the principle constituents of the soil cryptogamic crust (Anderson and Rushforth, 1978). The presence of the macroscopic lichens and mosses is noticeable even to the untrained observer. Even though the algae are inconspicuous, they are probably the most important component of the cryptogamic crust. The intertwining algal filaments and the tissues of the lichens and mosses are present throughout the top few millimeters of the soil and play an important role in soil stabilization in arid and semi-arid climates (Anatani and Marathe, 1974). The literature on cryptogamic crusts also documents their role in nitrogen fixation (Shields et al., 1957; MacGregor and Johnson, 1971; Henriksson and Simu, 1971; Reddy and Gibbons, 1974; Rychert and Skujins, 1974; Skujins and Klubek, 1978).

A recent study by Anderson et al. (1982) characterized the cryptogamic crust community in shadscale vegetation types throughout Utah and investigated the impact of grazing on their development. The results of the study suggests that the state of development of the cryptogamic community is an indicator of the present range condition.

The occurrence of cryptogamic soil crusts is not well understood. Many of the observations and experimentations with them has been in the western United States (Fletcher and Martin, 1942; Shields and Durrell, 1964; Lope and Gifford, 1972; Rychert and Skujins, 1974; Anderson and Rushforth, 1977; Anderson et al., 1982a; Anderson et al., 1982b). Well developed cryptogamic crusts have been observed in the Great Basin area,

the semi-deserts of the Colorado plateau, and in arid and semi-arid regions of Utah, Arizona, New Mexico, Colorado, and Wyoming. They have also been known from the Chihuahuan Desert and Altiplano regions of north-central Mexico and arid regions of India (Antani and Marathe, 1974; Singh, 1961).

The objective of the current project was to characterize the cryptogamic soil crust community in the sagebrush/greasewood, shadscale and juniper vegetation types on Tracts Ua and Ub. Once each community was characterized, an assessment of the potential use of the cryptogamic soil community to measure or monitor anthropogenic impacts in the area was made.

4.3.3.6.1 Materials and Methods

A. Sampling. Pertinent ecological data on cryptogamic species were collected from 15 sites previously established for vascular plant and wildlife studies (designated Cg on Figure 4.3-1). Five sites were located in the sagebrush/greasewood, five in the shadscale, and five in the juniper vegetation type. Sampling of cryptogams in the riparian vegetation type was not performed because of the frequent soil disturbances (flooding) and relatively high vascular plant cover and absence of a cryptogamic soil crust. At each site, 20 quadrats each 0.5 m x 0.5 m were placed along a linear transect paralleling the transect established for other vegetation and wildlife studies. Each quadrat was further subdivided into four equal sections (0.125 m x 0.125 m).

At each quadrat, the frequency of each cryptogamic species was noted by recording the presence of the species in each of the four subquadrats.

The total cover of cryptogamic species was ocularly estimated for the entire quadrat (0.25 m x 0.25 m) and the contribution of soil (terricolous) lichens, rock (saxicolous) lichens, mosses, and algae to the total cover was estimated and recorded as a percentage. Along each transect, a representative soil sample was collected and placed in a petri dish. The sample was later transported to the laboratory for identification of the algae present in the soil crust.

B. Species Identification Identification of the algae in the surface soil crust involves the inoculation of the soil sample with Bristols modified solution (Bischoff and Bold, 1963) and culturing for five days under 12-hour light regime at an intensity of approximately 1,000 foot candles. After the culture period, fresh mounts are made of the non-diatom algae. The algae are then identified and a relative density estimated. (It should be noted that some algae are not identifiable to species without elaborate culturing experimentation). Next, permanent diatom slides are made following standard techniques (Patrick and Reimer, 1966). All diatoms are identified and a relative frequency is determined by counting 100 diatoms and recording the percentage present of each species.

In addition to the soil crust removed for algal identification, a collection of mosses and lichens was also made at each site. Since pertinent frequency and cover data are collected in the field for both the mosses and lichens, only identification was necessary in the laboratory. Semi-permanent slides of the mosses and lichen were made. Moss and lichen nomenclature follows Flowers, 1973 and Hale and Culberson, 1975, respectively.

C. Data Analysis The data collected from the 20 quadrats was averaged by species and by life-form for each site. The frequency of occurrence for each species was determined by dividing the subquadrats of occurrence by the total subquadrats considered (80). The presence of each cryptogamic species is determined by dividing the number of quadrats of occurrence by the total number considered. Frequency was then multiplied by presence to give a Frequency/Presence (F/P) index from which the prevalent species were determined. The F/P index for the algae was calculated by multiplying the percentage present times a "commonness" factor. The "commonness" factors used were: 1 for rare; 2 for common; and 3 for abundant.

The number of prevalent species per vegetation type is equivalent to the average number of species present per stand. For example, the average number of terricolous lichen species in the juniper vegetation type is 3.0. Therefore, the three terricolous lichen species with the highest F/P index are listed as the most prevalent species for that vegetation type. The list of prevalent species was determined by life-form for each vegetation type.

The amount of cryptogamic cover is averaged for each life-form by vegetation type. Two sites in the shadscale and juniper vegetation type and one site in the sagebrush/greasewood lacked a developed soil cryptogamic crust. The two shadscale sites were on rocky, shaley slopes. The two juniper sites and the one greasewood site were also very rocky and the soil crust was absent. The presence of the saxicolous lichens at these five sites was recorded. However, frequency and cover data were not collected. Therefore, the average saxicolous lichen cover and the

F/P index values for many of the saxicolous lichens, which are based on five sites per vegetation type, are slightly underestimated.

4.3.3.6.2 Results and Discussion The frequency values for each cryptogamic species within each vegetation type are shown in Tables 4.3-7 through 4.3-9. The nine terricolous lichen species encountered in the juniper vegetation type were not found as frequently as the seven terricolous lichens in the greasewood vegetation type. There were also more mosses encountered per site in the greasewood type than in the shadscale and juniper vegetation types.

The occurrence of algae was essentially the same for the three vegetation types except for a slight increase of diatoms in the sagebrush/greasewood sites.

The total number of cryptogamic species per stand was highest in the juniper vegetation type. This is primarily due to the high number of saxicolous lichens in juniper compared with the shadscale and the sagebrush/greasewood types.

The cover data reported in Table 4.3-10 indicates some differentiation between sites. The 9.4%, 6.2%, and 8.5% cover for greasewood, shadscale, and juniper vegetation types are not statistically different, however, the makeup of that cover does vary and in the case of the amount of saxicolous lichen, cover is statistically different. The cryptogamic crust in the greasewood vegetation type has the best representation of the 4 different groups of cryptogams. An equal percentage of cover is attributable to the mosses and algae (26% and 27% respectively) and the terricolous lichens accounted for 21% of the total cryptogamic cover.

Table 4.3-7. Greasewood cryptogamic community characteristics.

CRYPTOGAMIC GROUP	[1]	Site No. 1	2	3	4	5	Avg.	S.D.	Index P X F
Terricolous Lichens									
Agrestia hispida	P	1			4		1.0	1.73	
	F	5			10		3.0	4.47	3.0
Candelariella vitellina	P			P*			P*		
	F								P*
Collema sp.	P	5	11	16	52.5		16.9	20.80	
	F	15	35	30	90		34.9	34.17	574.6
Dermatocarpon hepaticum	P	1	7.5	2.5	22.5		6.7	9.29	
	F	5	30	5	50		18.0	21.39	120.6
Endocarpon pusillum	P			P*			P*		
	F								P*
Fulgensia bracteata	P			1	4		1.0	1.73	
	F			5	15		4.0	6.52	4.0
Lecidea decipiens	P			P	2.5		0.5	1.12	
	F				10		2.0	4.47	1.0
No. spp./Site		3	2	4	5	0	3.6		

Saxicolous Lichens		Site No. 1	2	3	4	5	Avg.	S.D.	Index P X F
Acarospora strigata	P	1	10	4	4		3.8	3.90	
	F	5	25	5	10		9.0	9.62	34.2
Lecanora calcarea	P		1				0.2	0.45	
	F		5				1.0	2.24	0.2
Lecanora sp. (#700)	P			P*			P*	P*	
	F								P*
Lecidea sp. (#698)	P		P*				P*	P*	
	F								P*
Staurothele clopima	P		17.5		6		4.7	7.61	
	F		35		20		11.0	15.97	51.7
Verrucaria sphinctrinella	P				2.5		0.5	1.12	
	F				0.5		1.0	2.24	0.5
No. spp./Site		1	4	2	3	0	2.4		

Mosses		Site No. 1	2	3	4	5	Avg.	S.D.	Index P X F
Bryum argenteum	P			P*			P*		
	F								P*
Crossidium aberrans	P	P*					P*		
	F								P*
Pterygoneuron sp.	P	1		P*	2.5		0.7	1.10	
	F	5			5		2.0	2.74	1.4
Tortula ruralis	P	34	37.5	59	10		24.1	17.88	
	F	55	65	55	20		39.0	27.70	939.9
No. spp./Site		3	1	2	2	0	2.2		

[1] Presence

[2] Frequency

*Present but not encountered along transect.

Table 4.3-7 (Continued)

CRYPTOGAMIC GROUP	Site No.						Avg.[3]	Pres.	Inde
Algae Non-Diatoms	1	2	3a[1]	3b[2]	4	5	Freq.	(%)	P X
Calothrix parietana				R	C		3	40	120
Chlorococcum species		R	R		R		3	60	180
Chlorosarcina brevispinosa		R					1	20	20
Microcoleus vaginatus	A	A	A	A	A	A	15	80	1200
Nostoc commune				R	R		2	40	80
Nostoc muscorum			R-C		R-C		3	40	120
No. spp./Site	1	3	3	3	5	0	2.5		

	Site No.						Avg.	Pres.	Inde
Algae-Diatoms	1	2	3a	3b	4	5	Freq.	(%)	P X
Fragilaria species		R					1	20	20
Hantzschia amphioxys	R	C	C	C-A	C		9.5	80	760
Melosira species					R		1	20	20
Navicula mutica	R	A	A	A	A		13	80	1040
Nitzschia frustulum				R			1	20	20
Pinnularia borealis		R		R			2	40	80
Synedra species				R			1	20	20
No. spp./Site	2	4	2	5	3	0	2.7		

TOTAL NO. CRYPTOGAMS PER SITE	10	14	1	9	18	0	12.2		

[1]Site 3a samples taken from understory of vascular plants.

[2]Site 3b samples taken from interspace.

[3]Frequency based on commonnes index where R=1, C=2, and A=3.

Table 4.3-8. Shadscale cryptogamic community characteristics.

CRYPTOGAMIC GROUP		Site No.							Index
Terricolous Lichens		1	2	3	4	5	Avg.	S.D.	P X F
Agrestia hispida	P		10			1	2.2	4.38	
	F		25			5	6.0	10.84	13.2
Collema sp.	P		54		12.5	51	23.5	26.98	
	F		85		20	90	39.0	45.06	916.50
Dermatocarpon hepaticum	P		22.5		2.5	20	9.0	11.26	
	F		60		5	50	23.0	29.50	207.00
Fulgensia bracteata	P		7.5		4	6	3.5	3.43	
	F		20		10	20	10.0	10.0	35.0
Fulgensia fulgens	P				1	1	0.4	0.55	
	F				5	5	2.0	2.74	0.8
Lecidea decipiens	P		2.5			6	1.7	2.64	
	F		10			25	7.0	10.95	11.9
No. spp./Site		0	5	0	4	6	3.0		

		Site No.							Index
Saxicolous Lichens		1	2	3	4	5	Avg.	S.D.	P X F
Acarospora schleicheri	P					P*	P*	P*	
	F								P*
Acarospora strigata	P	P*	31	P*	7.5	4	8.5	12.46	
	F		70		20	15	21.0	28.81	178.5
Caloplaca trachyphylla	P					P*	P*	P*	
	F								P*
Candelariella vitellina	P					P*	P*	P*	
	F								P*
Lecanora alphoplaca	P		34		2.5	P*	7.3	14.96	
	F		55		5		12.0	24.14	87.6
Lecanora calcarea	P				1	5	1.2	2.17	
	F				5	20	5.0	8.66	6.0
Lecanora chrysoleuca	P					P*	P*	P*	
	F								P*
Lecidea tessellata	P					P*	P*	P*	
	F								P*
Staurothele clopima	P	P*	10	P*	11	P*	4.2	5.76	
	F		40		20		12.0	17.89	50.4
Verrucaria sphinctrinella	P			P*	5		1.0	2.24	
	F				10		2.0	4.47	2.0
Xanthoria elegans	P				4	P*	0.8	1.79	
	F				10		2.0	4.47	1.6
No. spp./Site		2	3	3	6	10	4.8		

		Site No.							Index
Mosses		1	2	3	4	5	Avg.	S.D.	P X F
Crossidium aberrans	P				P*		P*		
	F								P*
Pterygoneuron sp.	P				1	3.5	0.9	1.52	
	F				5	5	2.0	2.74	1.8
Tortula ruralis	P		29		19	26	14.8	13.99	
	F		55		35	55	29.0	27.70	429.2
No. spp./Site		0	1	0	3	2	1.2		

*Present but not encountered along transect.

[1]Presence
[2]Frequency

Table 4.3-8 (Continued)

CRYPTOGAMIC GROUP	Site No.						Avg.[3]	Pres.	Index
Algae Non-Diatoms	1	2	3	4	5a[1]	5b[2]	Freq.	(%)	P X F
Calothrix parietana		C-A			C-A		5	40	200
Chlorococcum species				R	R		2	40	80
Chroococcus minor					R		1	20	20
Chroococcus turgidus				R			1	20	20
Microcoleus vaginatus		A		A	A	A	12	60	720
Nostoc commune		R			R		2	40	80
Nostoc muscorum				R	C		3	40	120
No. spp./Site	0	3	0	4	6	1	2.3		

	Site No.						Avg.	Pres.	Index
Algae Diatoms	1	2	3	4	5a	5b	Freq.	(%)	P X F
Cocconeis pediculus		R					1	20	20
Cyclotella meneghiniana		R					1	20	20
Hantzschia amphioxys		R-C		C	R-C	R-C	6.5	60	390
Navicula mutica		R-C		A	R-C	R	7	60	420
Pinnularia borealis		R					1	20	20
No. spp./Site	0	5	0	2	2	2	1.8		

TOTAL NO. CRYPTOGAMS PER SITE	2	17	3	19	26		13.4		

[1] Crust sample taken from shrub understory.

[2] Crust sample taken from interspace.

[3] Frequency based on commonness index where R=1, C=2, A=3.

Table 4.3-9. Juniper cryptogamic community characteristics.

CRYPTOGAMIC GROUP		Site No.							Index
Terricolous Lichens		1	2	3	4	5	Avg.	S.D.	P X F
Agrestis hispida	P[1]	17.5	11			16	8.9	8.47	
	F[2]	45	25			35	21.0	20.43	186.9
Collema sp.	P	1	32.5			20	10.7	14.87	
	F	5	50			35	18.0	23.08	192.6
Dermatocarpon hepaticum	P		30			6	7.2	13.01	
	F		35			10	9.0	15.17	64.8
Diploschistis scruposus	P		6				1.2	2.68	
	F		15				3.0	6.71	3.6
Endocarpon pusillum	P	P*					P*		
	F								P*
Fulgensia bracteata	P		14				2.8	6.26	
	F		30				6.0	13.42	16.18
Lecidea decipiens	P		11				2.2	4.92	
	F		25				5.0	11.18	11.0
Lecidea russellii	P		P*	P*			P*		
	F								P*
Lecidea sp. (#698)	P		P*				P*		
	F								P*
No. spp./Site		3	8	1	0	3	3.0		

Saxicolous Lichens		Site No.							Index
		1	2	3	4	5	Avg.	S.D.	P X F
Acarospora chlorophana	P			P*	P*		P*		
	F								P*
Acarospora smaragdula	P	7.5		P*	P*		1.5	3.35	
	F	15					3.0	6.71	4.5
Acarospora strigata	P	40	12.5	P*	P*	37.5	18.0	19.64	
	F	90	40			85	43.0	43.82	774.0
Acarospora sp. (#733)	P	4		P*	P*		0.8	1.79	
	F	10					2.0	4.47	1.6
Candelariella vitellina	P	4		P*	P*		0.8	1.79	
	F	10					2.0	4.47	1.6
Lecanora alphoplaca	P	6		P*	P*		1.2	2.68	
	F	25					5.0	11.18	6.0
Lecanora calcarea	P					4	0.8	1.79	
	F					15	3.0	6.71	2.4
Lecanora chrysoleuca	P	11		P*	P*		2.2	4.92	
	F	35					2.0	15.65	15.4
Lecanora melanophthalma	P	11		P*	P*		2.2	4.92	
	F	35					7.0	15.65	15.4
Lecanora muralis	P	1		P*	P*		0.2	0.45	
	F	5					1.0	2.24	0.2
Parmelia pluttii	P			P*	P*		P*		
	F								P*
Staurothele clopima	P	67.5	5			6.1	26.7	34.42	
	F	90	15			90	39.0	46.96	1041.3
Verrucaria sphenctrinella	P	25	4				5.8	10.87	
	F	45	5				10.0	19.69	58.0
No. spp./Site		10	3	10	10	3	6.6		

*Present but not encountered along transect. [1]Presence [2]Frequency

Table 4.3-9 (Continued)

CRYPTOGAMIC GROUP		Site No.							Index
Mosses		1	2	3	4	5	Avg.	S.D.	P X F
Pterygoneuron sp.	P					1	0.2	0.43	
	F					5	1.0	2.24	0.2
Tortula ruralis/	P	6	5	P*		21	7.2	8.04	
Crossidium aberrans	F	25	10			40	15.0	17.32	108.0
No. spp./Site		1	1	1	0	2	1.0		

	No.					Avg.[1]	Pres.	Index
Algae Non-Diatom	1	2	3	4	5	Freq.	(%)	P X F
Calothrix parietana		C-A			R-C	4	40	160
Chlorococcum species		R				1	20	20
Chroococcus minor		R				1	20	20
Chroococcus trugidus		R				1	20	20
Gloeocapsa nigrescens		R				1	20	20
Microcoleus vaginatus		A			A	6	40	240
Nostoc commune		C			R-C	3.5	40	140
No. spp./Site	0	7	0	0	3	2.0		

	Site No.					Avg.[1]	Pres.	Index
Algae Diatom	1	2	3	4	5	Freq.	(%)	P X F
Hantzchia amphioxys		C			C	4	40	160
Navicula mutica		C			A	5	40	200
Navicula species					R	1	10	10
Nitzschia inconspicua					R	1	10	10
Pinnularia borealis		R				1	10	10
No. spp./Stand	0	3	0	0	4	1.4		

TOTAL NO. CRYPTOGAMS PER SITE	14	22	12	10	15	14.6	

*Present but not encountered along transect.

[1] Frequency based on commonness index where R=1, C=2, and A=3.

Table 4.3-10. Cryptogamic cover characteristics by vegetation type.

Greasewood

	Site Number						
Cover Type	1	2	3	4	5	Avg.	S.D.
Total Cryptogam	10.9	8.7	17.4	10.0	0	9.4	6.22
Terricolous lichen	0.2	1.7	2.4	6.8	0	2.2	2.75
Saxicolous lichen	0.3	2.4	0.1	0.1	P*	0.6	1.02
Moss	4.9	3.7	6.0	0.8	0	3.1	2.59
Algae	5.5	0.9	8.9	2.3	0	3.5	3.66

Shadscale

	Site Number						
Cover Type	1	2	3	4	5	Avg.	S.D.
Total cryptogam	0	9.5	0	8.1	13.5	6.2	6.01
Terricolous lichen	0	3.2	0	0.5	8.3	2.4	3.56
Saxicolous lichen	P*	310	P*	2.8	0.6	1.3	1.50
Moss	0	3.1	0	2.6	2.6	1.7	1.53
Algae	0	0.1	0	2.1	2.0	0.8	1.11

Juniper

	Site Number						
Cover Type	1	2	3	4	5	Avg.	S.D.
Total cryptogam	7.0	25.2	P*	P*	10.2	8.5	10.33
Terricolous lichens	0.3	13.5	0	0	1.2	3.0	5.89
Saxicolous lichens	6.5	6.4	P*	P*	7.0	4.0	3.64
Mosses	0.1	0.5	0	0	1.8	0.5	0.77
Algae	0	4.9	0	0	0.2	1.0	2.17

*Present but not encountered along transect.

This vegetation type supported the most well-developed cryptogamic crust.

The shadscale vegetation type also supports a well developed crust; however, the mosses and especially the algae contributed less to the total cryptogamic cover. The saxicolous lichens accounted for about twice as much cover as in the greasewood vegetation zones.

The cryptogamic cover encountered in the juniper vegetation type was primarily due to saxicolous lichens. Nearly 80% of the total cover was attributable to saxicolous lichens. The amount of moss cover was appreciably lower than in the other two vegetation types. Terricolous lichen cover ranged from 13.5% at Site VJ-2 to near 0 for sites VJ-1, VJ-3 and VJ-4. The high variability of total cryptogamic cover (10.33) is somewhat of an indication of the heterogeneity of the juniper sample sites based on the non-vascular community. Of the three sites sampled, site VJ-2 supported the most well developed soil cryptogamic crust. The other two sites sampled, VJ-1 and VJ-5, showed moderate total cover with a greater contribution of saxicolous lichens.

Previous studies on cryptogamic crust communities (Anderson et al., 1982a; and Anderson et al., 1982b) in regions vegetationally similar to Tracts Ua and Ub revealed that certain cryptogamic species such as algae are more resistant to disturbances, particularly grazing. It was also shown that the occurrence of many terricolous lichens and mosses decreased dramatically when the area was under heavy grazing pressure. The saxicolous lichens were least impacted, which is understandable. However, the fact that the occurrence of algae in the soil was the next least disturbed cryptogamic life form was somewhat unexpected. The fact

that algae present in the soil crust are resistant to disturbance and that similar species were found at all sample sites, give some indication of the ubiquity of soil algae and their importance in the soil biological ecosystems. The potential use of soil algae in reclaiming disturbed soils should not be underestimated and will be the subject of further investigation.

The juniper vegetation type supported a well developed saxicolous lichen community. The juniper vegetation type was observed throughout much of the project area and suggests the potential use of certain lichen species as biological monitors of atmospheric pollutants, such as SO_2. Lichens, primarily the foliose forms, are sensitive to relatively low levels of pollutants in comparison to levels found to be deleterious to vascular plants. Mosses to some extent have also been used to detect critical concentration levels of pollutants. Whichever is used, the potential does exist for using cryptogamic species, primarily foliose lichens, to monitor levels of air pollutants.

4.3.3.7 Soil Microbiology Study Soil bacteria and soil fungi play a number of roles central to the structure, function, and rehabilitation of cold desert ecosystems. Most are decomposers that break down soil organic matter, and maintain the availability of essential plant nutrients. Others, such as Rhizobium bacteria and vesicular-arbuscular (VA) mycorrhizal fungi fix atmospheric nitrogen or aid in plant uptake of soil nutrients and water. In these capacities, soil microorganisms regulate biogeochemical cycles, affect the net primary productivity of plant communities, enhance plant vigor and survival, and speed rates of ecosystem development/restoration.

Impacts of oil shale development on populations of soil microbes are potentially numerous. Changes in soil chemistry resulting from atmospheric pollution may directly enhance or impair microbiological activities. Indirect effects mediated through impacts on plant productivity and levels of soil organic matter, are also possible. In turn, soil microbiology may directly influence processes tangent to oil shale development. Successful revegetation of processed shale disposal sites, for example, will require managing populations of bacteria and fungi in topsoil and shale substrates.

This section presents results of the 1981 monitoring program undertaken to assess impacts of oil shale development and provide baseline data on the microbiology and chemistry of soils in the White River tracts. Also reported are results of an auxillary study designed to assess natural populations of Rhizobium bacteria and VA mycorrhizal fungi in White River soils.

4.3.3.7.1 Methods and Materials

A. Sampling In April, June, August, October, and December, 1981 soils were sampled at eight sites within the White River tracts. The sites were VS-1 and VS-4 (shadscale), VG-1, VG-2 and VG-3 (greasewood), VJ-1 and VJ-5 (juniper), and VR-2 (riparian) as shown in Figure 4.3-1. April and June surveys were exploratory, and sampling routines varied. Results from these collections, however, were used to establish the following scheme that was employed in August, October and December.

Along each transect, soils were collected at two depth intervals, 0-5 cm and 5-15 cm, from beneath six mature individuals of sagebrush.

Four 0-5 cm cores and two 5-15 cm cores were taken under each shrub. Soils from shrubs 1 and 2, 3 and 4, and 5 and 6 were pooled giving three 0-5 cm composite samples and three 5-15 cm composite samples per transect. As such, a total of 48 samples were collected during each sampling period.

During 1981, 319 total soil samples were taken from the eight sites. Samples were taken in tandem with those collected for soil invertebrate analyses (see Section 4.3.4). Spot soil temperature measurements at 5 cm depth were taken at the time of sampling.

In December 1981, three soil samples were collected at each of the eight sites used in the soil monitoring program for Rhizobia and mycorrhizal fungal analyses. A sample consisted of 2-3 soil cores collected from the 0-15 cm depth interval beneath a single shrub. In this study, shrub species were varied to include rubber rabbitbrush (Chrysothamnus nauseosus, CHNA), shadscale (ATCO), Utah juniper (JUOS), sagebrush (ARTR), gray horsebrush (Tetrademia canescens, TECA), douglas rabbitbrush (Chrysothamnus viscidiflorus, CHVI), and greasewood (SAVE).

B. Analyses Samples were taken to laboratories at Native Plants, Inc., and Utah State University for chemical and microbiological analyses. Textures (percent sand, silt, and clay) were determined using the Bouyoucos hydrometer method (Bouyoucos, 1961). Moisture contents were measured gravimeterically (Gardner, 1965). Electrical conductivities (EC's) and pH's were determined electrometrically on 1:1 soil-water extracts (Bower and Wilcox, 1965; Peech, 1965). Organic carbon and total nitrogen were measured on a CHN analyzer. Ammonium nitrogen (NH_4-N), nitrite-nitrogen (NO_2-N), and nitrate-nitrogen (NO_3-N) were

determined colorimetrically from soil extracts (Bremmer, 1965). Organic nitrogen was calculated as: total N - (NH_4-N + NO_2-N + NO_3-N). Carbon to nitrogen (C/N) ratios for soil organic matter were calculated as: % organic carbon/% organic nitrogen. Total lengths of fungal hyphae per gram of soil were determined by direct microscopic counts (Paul and Johnson, 1977). Bacterial populations (colony forming units of CFU's) were counted using dilution plate techniques (Clark, 1965). Soil respiration (meq CO_2 evolved/g·hr) was measured via barium hydroxide titration (Elican and Moore, 1962). Dehydrogenase activity was determined using the tetrazolium/chloride technique (Casida et al., 1964). Most methods are described in detail in the WRSP Environmental Monitoring Manual.

All analyses were performed on sieved (2 mm), thoroughly mixed samples. Microbiological analyses were performed on soils at their field moisture contents. Textural and chemical analyses were performed on air-dry samples.

Soil for the Rhizobia and mycorrhizal fungi analyses were returned to laboratories at Native Plants where they were sieved (4 mm) and then diluted with an autoclaved sand-loam mix to concentrations of 100% (no sand-loam mix added), 50%, 20%, 10%, 5%, 1%, and 0.1% (1 part soil: 999 parts sand-loam mix). Dilutions were thoroughly mixed and then dispensed into 160 cm^3 plastic leach tubes; three tubes per dilution, 21 tubes per soil type. Suitable controls containing only autoclaved sand-loam mix were prepared in parallel. Tubes were sown with yellow sweet clover, mulched with autoclaved white quartz sand, and placed in random block design on a greenhouse bench under artificial lighting (18 hour

photoperiod). Following emergence, plants were thinned to three per pot. They were watered regularly, and fertilized once a month with half-strength Hoagland's solution (Hoagland and Arnon, 1950) minus phosphorus. Nutrients were applied sparingly to avoid suppressing the formation of root associations.

After eight weeks, the plants were harvested. Shoot heights were measured, roots were washed, and the presence or absence of Rhizobium nodules was recorded. Roots were then cut into 1 cm segments and a random sample was taken for analysis of VA mycorrhizal infection (Kormanik et al., 1980; Biermann and Lindermann, 1981). Infection intensities were measured as the percent total root length colonized by VAM fungi.

4.3.3.7.2 Results

A. Soil Texture Surface (0-15 cm) soils on the tracts contained 45-75% sand, 20-45% silt, and 5-10% clay. Table 4.3-11 summarizes textural information by transect and depth. Briefly, sandy loams predominated. Only soils at sites VS-1 and VR-2, with relatively high silt contents, classified as loams. Textures did not vary significantly with depth in the upper 15 cm of upland soils. In the riparian zone, silt contents were noticeably higher in the 0-5 cm layer; presumably a result of alluvial deposition. As expected, there were no seasonal trends in soil texture.

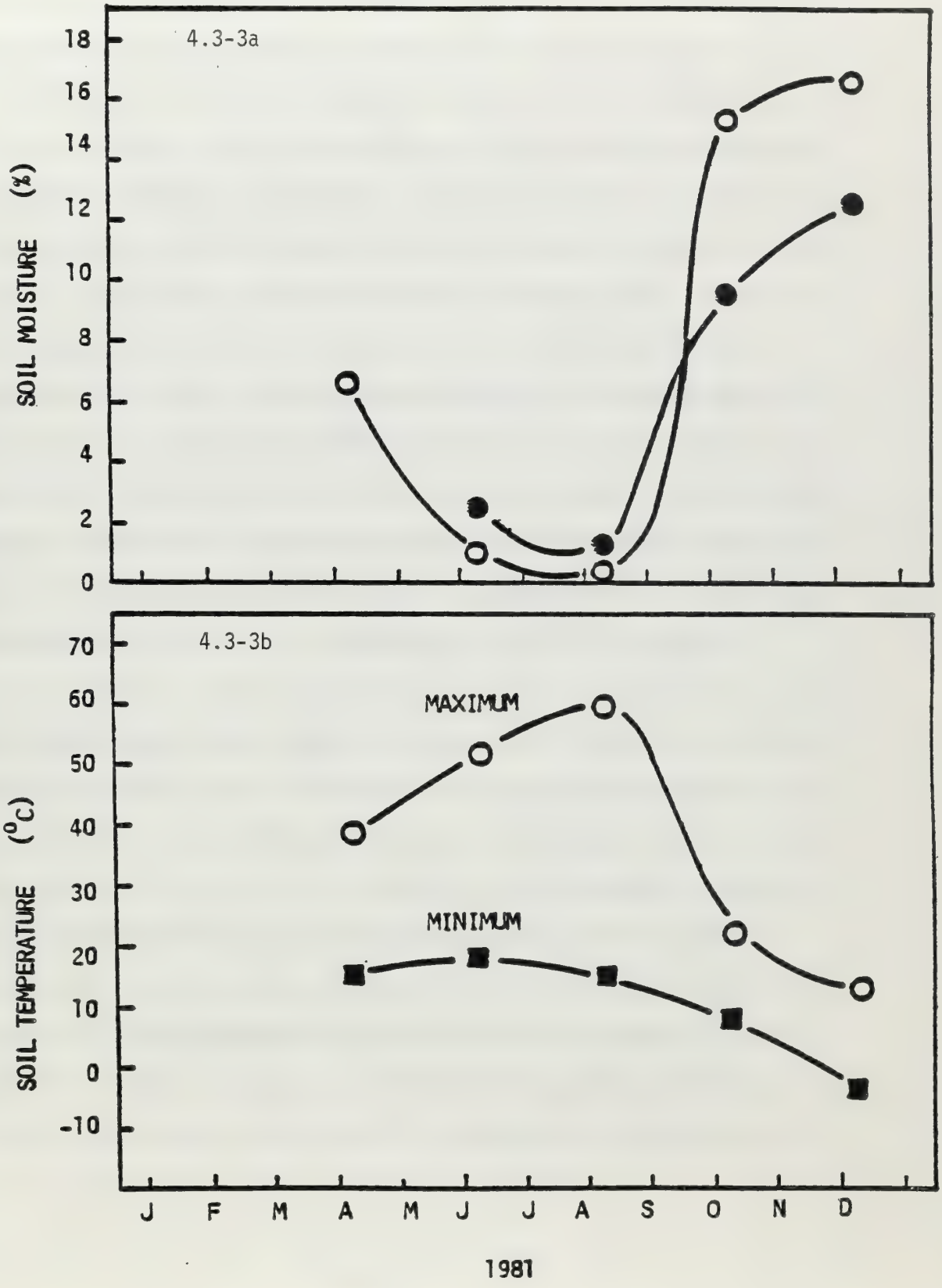
B. Soil Moisture Contents and Temperature Field moisture contents of tract soils fluctuated dramatically during the eight-month study period (Figure 4.3-3a). April samples contained 6.6 $\pm$ 4.4% moisture;

Table 4.3-11. 1981 annual means ($\bar{X} \pm S$) for textural, chemical, and microbiological characteristics of soils. Values are given by transect and depth interval.

Variable	Units	Depth	Site VS1	VS4	VG1	VG2	VG3	VJ1	VJ5	VR2
Sand	%	0-5	56 ± 5	72 ± 8	73 ± 6	72 ± 4	65 ± 6	68 ± 5	73 ± 5	44 ±17
		5-15	51 ± 7	66 ±10	73 ± 6	70 ± 7	69 ± 6	63 ± 7	69 ± 5	55 ±13
Silt	%	0-5	33 ± 3	20 ± 4	21 ± 3	22 ± 4	27 ± 3	25 ± 3	21 ± 2	46 ±15
		5-15	37 ± 4	24 ± 5	21 ± 3	23 ± 3	24 ± 3	28 ± 4	23 ± 3	37 ±14
Clay	%	0-5	11 ± 2	8 ± 2	6 ± 2	6 ± 2	8 ± 3	7 ± 2	6 ± 2	10 ± 3
		5-15	12 ± 4	10 ± 4	6 ± 2	7 ± 2	7 ± 3	9 ± 2	8 ± 3	8 ± 3
Moisture	%	0-5	6.7± 5.4	5.6± 4.4	5.0± 4.3	7.1± 5.4	9.1± 9.0	6.5± 5.7	6.0± 5.8	12.1±11.7
		5-15	6.2± 5.4	7.7± 4.8	4.2± 3.9	7.0± 5.2	8.7± 7.1	5.6± 4.6	6.4± 4.9	7.4± 7.4
pH		0-5	8.0± 0.4	8.3± 0.3	7.9± 0.3	8.0± 0.3	8.1± 0.3	7.9± 0.2	8.0± 0.3	8.0± 0.3
		5-15	8.3± 0.3	8.3± 0.4	8.5± 0.5	8.2± 0.1	8.2± 0.1	8.3± 0.3	8.4± 0.4	8.2± 0.2
EC	mmho/cm	0-5	0.49±0.12	0.34±0.15	0.29±0.10	0.30±0.06	0.44±0.19	0.28±0.08	0.36±0.12	0.58±0.20
		5-15	0.27±0.09	0.25±0.09	0.19±0.06	0.21±0.05	0.29±0.12	0.20±0.06	0.26±0.11	0.35±0.17
Organic Carbon	%	0-5	1.41±0.43	0.81±0.25	0.92±0.34	0.84±0.24	0.89±0.28	1.09±0.36	1.01±0.35	0.93±0.33
		5-15	1.08±0.17	0.62±0.26	0.60±0.33	0.63±0.16	0.66±0.18	0.67±0.20	0.76±0.21	0.64±0.30
Organic Nitrogen	%	0-5	0.18±0.07	0.10±0.09	0.09±0.04	0.08±0.03	0.09±0.04	0.16±0.16	0.10±0.04	0.14±0.09
		5-15	0.08±0.07	0.08±0.06	0.03±0.03	0.06±0.02	0.06±0.01	0.04±0.04	0.04±0.04	0.04±0.04
C/N Ratio		0-5	7.9± 1.4	10.5± 6.6	11.1± 3.2	11.4± 3.9	10.7± 3.5	9.7± 3.6	11.0± 3.0	8.5± 2.7
		5-15	8.1± 8.4	9.3± 3.2	11.9± 3.8	12.0± 4.4	11.3± 2.8	9.6± 1.7	10.6± 1.3	10.4± 3.3
NH_4-N	µg/g	0-5	4.2± 2.3	2.7± 1.1	2.9± 1.6	2.2± 1.0	2.3± 1.2	2.5± 1.5	2.4± 1.4	3.9± 5.6
		5-15	3.0± 2.2	1.9± 1.6	1.2± 0.5	1.7± 1.5	1.3± 0.5	1.3± 0.6	1.4± 0.5	1.6± 0.6
NO_2-N	µg/g	0-5	0.5± 0.6	0.2± 0.2	0.3± 0.4	0.3± 0.4	0.4± 0.5	0.3± 0.4	0.3± 0.3	0.4± 0.6
		5-15	0.6± 0.5	0.4± 0.4	0.4± 0.4	0.4± 0.4	0.5± 0.3	0.5± 0.4	0.5± 0.3	0.8± 0.9
NO_3-N	µg/g	0-5	11.0± 8.3	7.4±10.1	7.6± 5.0	5.3± 4.3	14.2±13.2	5.6± 6.2	7.1± 6.0	23.7±27.0
		5-15	3.9± 2.2	2.8± 1.9	12.5±27.9	2.1± 1.2	7.7± 5.0	1.6± 0.8	3.3± 2.4	14.9±17.0
Total Bacteria	10^6CFU/g	0-5	4.8± 2.3	3.0± 3.0	6.3± 8.7	4.9± 7.7	15.2±47.2	4.9± 7.4	6.9±19.1	18.9±37.9
		5-15	3.6± 1.9	4.4± 3.6	3.9± 2.9	2.6± 2.2	2.6± 1.8	3.1± 3.0	3.4± 2.7	6.3± 3.9
Total Fungi	m hyphae/ g	0-5	90 ±45	48 ±25	44 ±16	64 ±27	65 ±29	67 ±28	79 ±43	74 ±55
		5-15	98 ±64	97 ±36	45 ±26	49 ±20	71 ±35	135 ±62	101 ±46	68 ±35
Respiration	10^{-4}meq CO_2/g·hr	0-5	34 ±19	33 ±30	31 ±17	30 ±20	34 ±18	35 ±19	32 ±19	51 ±28
		5-15	26 ±14	30 ±18	21 ±10	28 ± 7	22 ±11	28 ±18	25 ±11	40 ±15
Dehydrogenase Activity	mg formazan/ liter	0-5	27 ±11	21 ± 9	24 ± 9	18 ± 9	20 ±10	21 ± 8	21 ± 6	18 ±16
		5-15	18 ± 7	12 ±10	7 ± 4	8 ± 3	9 ± 2	9 ± 3	12 ± 4	11 ± 7

Figure 4.3-3a. Monthly mean moisture contents for 0-5 cm (o) and 5-15 cm (•) soils. All sites are included.

Figure 4.3-3b. Monthly maximum and minimum spot soil temperatures measured at approximately 5 cm depth.



June samples 1.8 ± 1.2% moisture; August samples, 0.8 ± 0.5% moisture; October samples, 12.5 ± 6.8% moisture; and December samples 14.6 ± 5.5% moisture. During summer months, moisture contents were generally 1% - 2% higher in subsurface (5-15 cm) soils than in surface (0-5 cm) soils. In October and December, surface soils generally contained 4-6% more moisture than subsurface soils. There were few differences between upland sites in soil moisture contents. Riparian soils were generally more moist than upland soils, although due to high variability, differences were not statistically significant.

Figure 4.3-3b plots the maximum and minimum spot soil temperatures that were recorded during each sampling period. Maxima were generally recorded during mid-afternoon (1300-1500 hours); minima in early to mid-morning (800 - 1100 hours). Results show that the highest soil temperatures and largest ranges occurred in June-August. The lowest temperatures and narrowest ranges were found in October-December.

C. pH and EC Soil pH averaged 8.0 ± 0.3 in the 0-5 cm zones and 8.3 ± 0.3 in the 5-15 cm zones of White River soils. (These values are geometric means for all 1981 samples.) The slightly lower alkalinities of the surface soils may reflect their higher organic matter and organic acid contents. There were no significant differences in soil pH between transects or between sampling dates.

Electrical conductivities averaged 0.39 ± 0.17 mmho/cm in the 0-5 cm soil zone and 0.25 ± 0.11 mmho/cm in the 5-15 cm soil zone (all sites , all dates). The difference in EC between depths is statistically significant (t-test; $p \leq 0.001$), and it presumably reflects salt accumulation from surface evaporation. Soils at sites VS-1, VG-3, and VR-2 had

the highest EC, presumably a result of their higher silt contents and reduced drainages (see Table 4.3-12). No consistent seasonal trends in soil electrical conductivity were evident.

C. Organic Carbon and Nitrogen Contents Mean organic carbon contents of tract soils (all transects) declined steadily from 1.06 ± 0.42% in April to 0.73 ± 0.28% in December. Organic nitrogen decreased also from 0.13 ± 0.09% in April to 0.08 ± 0.04% in December. These declines presumably reflect microbial decomposition of above and belowground litter. There were few differences between sites in soil organic matter content. Soils at site VS-1 had generally higher levels of organic carbon and nitrogen than other soils, but the significance of this difference is difficult to assess given that all samples were collected from relatively organic-matter-rich zones beneath shrubs. On the average, surface soils (0-5 cm) contained 30% more organic carbon and nitrogen than subsurface (5-15 cm) soils. Carbon to nitrogen (C/N) ratios were relatively constant between sample dates, sites, and soil depths.

E. Inorganic Nitrogen Fractions The inorganic nitrogen contents of tract soils were relatively low. Ammonium-nitrogen averaged 2.6 ± 2.3 ug/g, nitrite-nitrogen averaged 0.4 ± 0.4 ug/g, and nitrate-nitrogen averaged 9.1 ± 13.2 ug/g (all transects, all dates). Levels of NH_4-N and NO_3-N were generally higher in 0-5 cm soils than in 5-15 soils, and soils collected at sites VS-1, VG-3, and VR-2 tended to have higher inorganic nitrogen contents than soils collected in other areas (Table 4.3-11). However, high variabilities between samples yielded these differences statistically insignificant. No seasonal trends in the inorganic nitrogen contents were evident.

Table 4.3-12. Correlation coefficients linking the textural, chemical, and microbiological parameters measured for soils. All 319 samples collected in 1981 are included in this analysis. Only relationships for which $p \leq 0.01$ are listed.

	Sand	Silt	Clay	Moisture	pH	EC	Organic Carbon	Organic Nitrogen	NH_4-N	NO_2-N	NO_3-N	Total Bacteria	Total Fungi	Respiration	Dehydrogenase Activity
Sand		-0.91	-0.59			-0.42	-0.33		-0.22		-0.23	-0.19	-0.23		
Silt			0.37	0.18		0.43	0.26	0.18	0.15			0.19	0.24		
Clay				0.17		0.18	0.18		0.27	0.26					
Moisture										0.51	0.22	0.20	-0.18	0.44	0.29
pH						-0.36	-0.32	-0.31	-0.20	-0.23					-0.28
EC							0.54	0.30	0.42		0.36			0.21	0.33
Organic Carbon								0.53	0.33			0.15	0.35		0.33
Organic Nitrogen									0.41					0.16	0.18
NH_4-N										0.22		0.15		0.35	0.32
NO_2-N													-0.24	0.23	0.46
NO_3-N												0.21		0.22	
Total Bacteria														0.18	
Total Fungi															
Respiration															0.22
Dehydrogenase Activity															

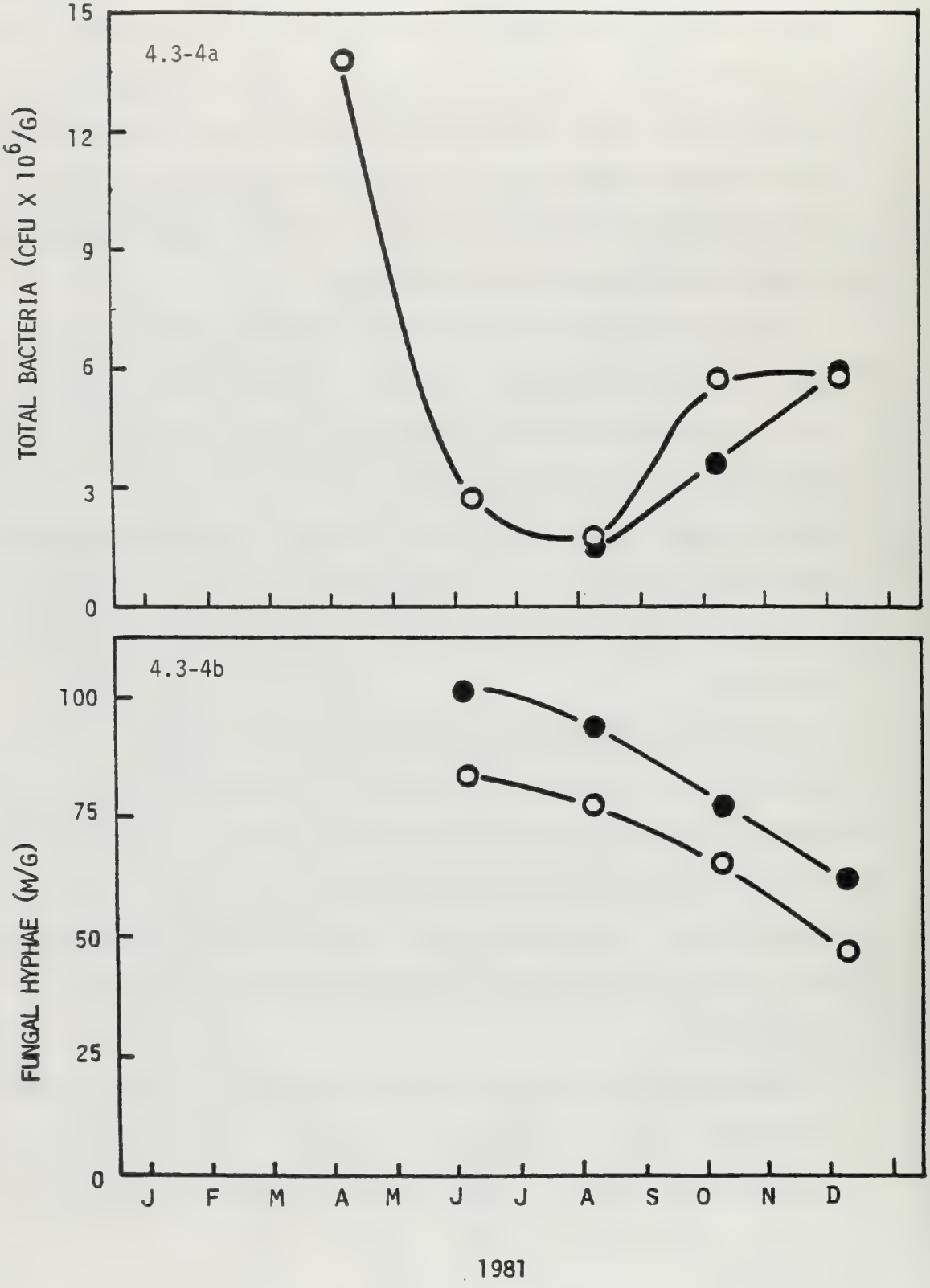
F. Total Bacteria and Fungi Soil bacterial populations fluctuated markedly over the study period (Figure 4.3-4a). Factors governing these fluctuations will be discussed later. On the average, bacterial counts were 35-40% lower in 5-15 cm soils than in 0-5 cm soils although these differences were significant only in October (Figure 4.3-4a). Because sample variances were high, no significant differences in bacterial populations between transects were noted, although riparian soils seemed to support higher numbers than upland soils.

Fungal populations in 0-5 cm soils declined continuously from a maximum in June to a minimum in December (Figure 4.3-4b). Subsurface (5-15 cm) populations behaved similarly, but were consistently higher than surface (0-5 cm) populations by 20%. Again, high sample variances precluded detection of significant differences in fungal populations between sites. However, VS-1 soils seemed to support the highest surface populations, while VJ-1 and VJ-5 soils supported the highest subsurface populations.

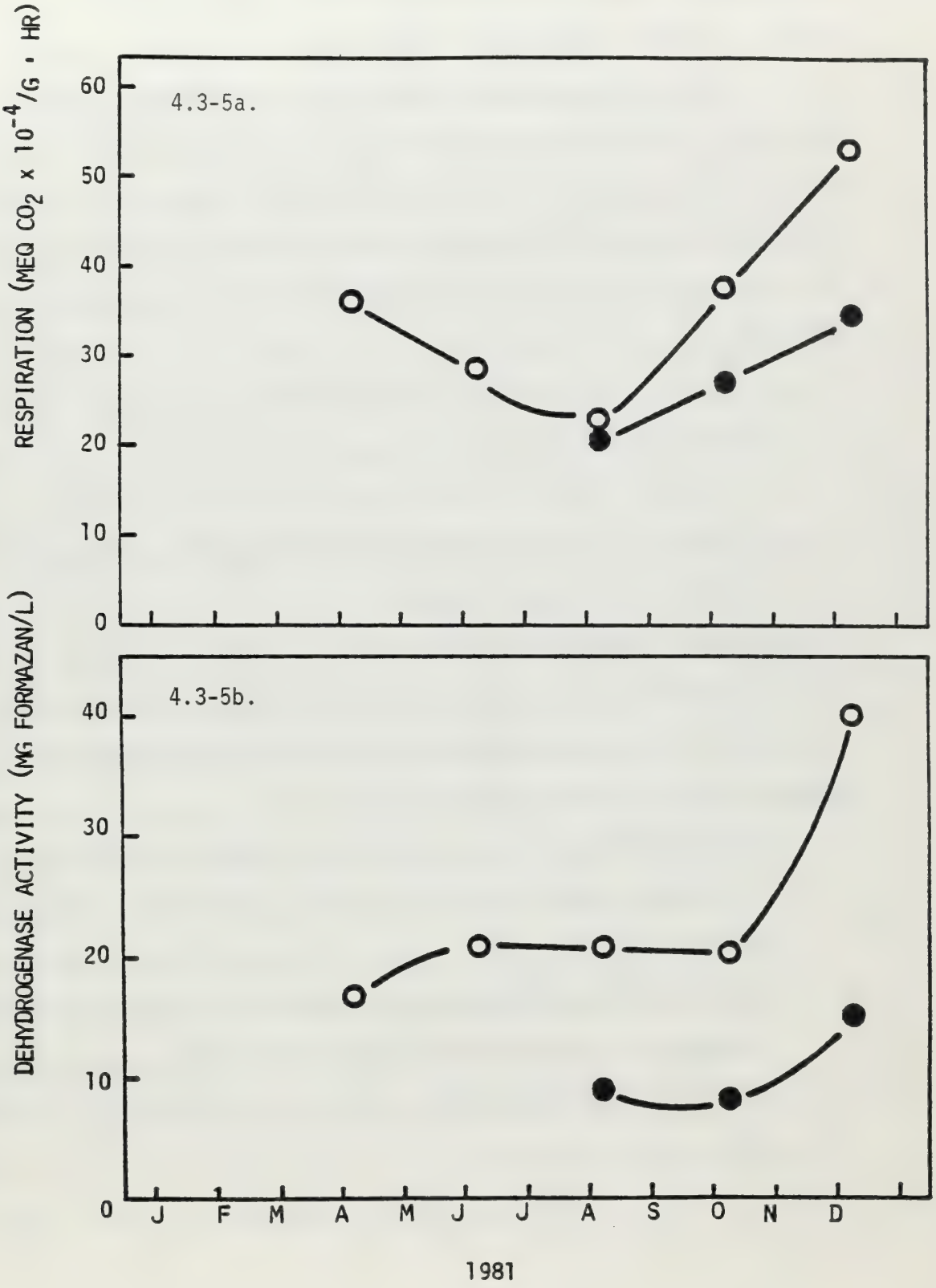
G. Respiration and Dehydrogenase Activities Mean rates of respiration in 0-5 cm soils (all transects) declined from April to August then rose from October to December (Figure 4.3-5a). Rates in 5-15 cm soils rose from August to December and were consistently lower than rates in surface soils. Respiratory activities were similar between all upland soils. Riparian soils seemed to support the highest rates of respiration.

Dehydrogenase activities in surface (0-5 cm) soils rose from April to June, then reached a plateau until October. They then rose again in December (Figure 4.3-5b). Dehydrogenase activities in subsurface

Figures 4.3-4a. and 4b. Monthly mean total bacterial and total fungal counts for 0-5 cm (o) and 5-15 cm (•) soils. All sites are included.



Figures 4.3-5a. and 5b. Monthly mean respiration rates and dehydrogenase activities for 0-5 cm (o) and 5-15 cm (•) soils. All sites are included.



(5-15 cm) soils were roughly half those measured in surface soils. No significant differences were evident between sites, although VS-1 soils seemed to support above average dehydrogenase activities.

H. Correlations between Chemical and Microbiological Factors

Correlation coefficients linking the 15 variables measured for tract soils are given in Table 4.3-12. This analysis includes all samples collected during 1981. Only relationships for which $p \leq 0.01$ are listed. Correlations linking textural and chemical characters show the following:

- Soils with relatively low sand contents are relatively high in both silts and clays.
- Finer soils tend to be more moist and to have higher EC's.
- Finer soils tend to have higher organic carbon, organic nitrogen, and mineral nitrogen contents.
- Higher organic matter and mineral nitrogen contents are consistently associated with lower soil pH's and higher EC's.

Correlations linking microbiological parameters with physical and chemical characteristics indicate the following:

- Populations of bacteria and fungi are higher in soils with relatively high silt, organic carbon, and mineral nitrogen contents.
- High bacterial populations are associated with high soil moisture contents. Fungi show the opposite relationship.
- Bacterial and fungal numbers were not associated with soil pH or EC.

- o Higher rates of soil respiration and dehydrogenase activity were associated with higher soil moistures, EC's, organic carbon contents, organic nitrogen contents, and mineral nitrogen contents, but not with high microbial populations.

In general, the coefficients given in Table 4.3-12 are low (± 0.2-0.5) but this is not surprising given that all sampling periods, depth intervals, and sites are included. Coefficients for soils collected from a given depth on a given date were generally higher (±0.4-0.6) but significance ratings were no different. The sets of significant relationships varied slightly from month to month, but the most consistent relationships all appear in the annual statistics discussed above.

I. Rhizobia and Mycorrhizal Fungi On the average, undiluted soils on tract produced 60 ± 28% VAM infection on M. officinalis roots after eight weeks (Table 4.3-13). Infection intensities declined continuously with increasing soil dilutions and reached extinction only at the highest dilution. No marked differences appeared in VAM inoculation potentials between sites. However, soils collected at sites VG-2 and VG-3 may have had slightly lower VAM fungal populations as most samples collected in these areas lost their infectivities at the 1% dilution level.

Most shrub species seemed to support active VAM fungal populations in their underlying soils. The two samples collected from beneath sarcobatus vermiculatus (greasewood) however, produced negligible infections. Sarcobatus is presumably non-mycrorrhizal and may produce compounds inhibitory to VAM fungi. This would explain in part the lower VAM infectivities of transect VG-2 and VG-3 soils.

Table 4.3-13. VAM infection results for the soil bioassay. Values are in percent root length colonized by VAM fungi. Means and standard deviations for three replicates are given.

		% Soil in Dilution						
Sample	Species	100	50	20	10	5	1	0.1
VS1:1	ARTR	50±15	30±40	25±20	20±20	4±4	3±3	0±0
VS1:2	ATCO	80±15	95±2	75±5	45±15	40±40	10±10	0±0
VS1:3	TECA	60±13	45±5	15±10	15±15	5±5	5±5	0±0
VS4:1	ARTR	50	70	50	30	7	0	1
VS4:2	CHVI	70±10	60±10	35±15	15±10	15±10	10±5	0±0
VS4:3	ATCO	80	70±30	55±35	30±10	50±25	20±15	0±0
VG1:1	ARTR	75±15	55±20	55±15	40±15	40±15	5±5	2±3
VG1:2	CHNA	70	45±30	35±30	30±35	5±5	2±3	0±0
VG1:3	CHNA	90±10	85±10	70±20	65±25	15±10	20±35	0±0
VG2:1	ARTR	85±15	65±25	45±15	35±15	20±30	5±0	1±1
VG2:2	SAVE	0±0	0±0	2±2	0±0	0±0	0±0	0±0
VG2:3	CHNA	40±30	20±25	5±0	15±15	5±4	0±0	0±0
VG3:1	ARTR	80±15	70±5	50±15	55±30	5±10	0±0	0±0
VG3:2	ARTR	80±15	35±10	30±45	7±3	7±3	0±0	1±2
VG3:3	SAVE	1±2	3±6	0±0	0±0	0±0	0±0	0±0
VJ1:1	ARTR	75±15	60±25	25±15	10±5	15±20	2±2	0±0
VJ1:2	CHVI	85±3	80±10	80±5	40±15	20±15	15±20	0±0
VJ1:3	JUOS	30±20	50±20	30±20	15±5	5±10	10±10	0±0
VJ5:1	ARTR	40±10	40±30	30±25	20±5	30±10	15±10	0±0
VJ5:2	JUOS	70±10	80±10	50±35	40±25	5±10	20±25	0±0
VJ5:3	ARTR	90±10	65±55	40±35	40±30	55±40	5±5	0±1
VR2:2	CHNA	2±3	15±15	1±1	1±1	2±3	1±1	0±0
VR2:3	CHNA	80±10	45±10	45±20	40±5	30±20	10±15	0±0
Control	---	0	0	0	0	0	0	0
All Samples		60±30	50±25	35±25	25±20	15±15	7±7	0±1

Results for rhizobial nodulation were spotty. On the average, nodulation was unaffected by soil dilution (Table 4.3-14). Forty to 50% of the plants at all dilutions formed nodules. Furthermore, there were no distinct differences between sites or shrub types with the exception that soils collected from beneath rubber rabbitbrush seemed to produce the most consistently strong infections.

VAM infection had no impact on plant height, but nodulation did. Plants infected with Rhizobia averaged 19.6 $\pm$ 3.2 cm. This difference is statistically significant (t-test; $p \leq 0.001$). It was noticed that plants infected with Rhizobium were also greener and more vigorous in appearance that non-nodulated plants. This indicates that the infective strains of bacteria were also effective nitrogen fixers.

4.3.3.7.3 Discussion The 1981 soils monitoring program was exploratory and a full annual cycle of post-Baseline measurements will be completed in 1982. Nevertheless, a working understanding of the chemical and microbiological relationships with tract soils is emerging. The major conclusions that can be drawn to date include the following:

(1). Populations of soil bacteria fluctuate markedly during the year, presumably in response to changes in soil moisture, soil temperature, and soil organic matter content. Peak populations occur in the spring. Mixima are reached in the summer.

(2). Populations of soil fungi presumably fluctuate through an annual cycle as well, although the nature and timing of that cycle remain unclear. In contrast with bacterial numbers, mean hyphal lengths declined continuously from June through December, and correlations with soil

Table 4.3-14. Rhizobium nodulation results for the soil bioassay. Values give the percentage of the plants in each treatment that formed nodules.

		% Soil in Dilution						
Sample	Species	100	50	20	10	5	1	0.1
VS1:1	ARTR	0	0	100	100	100	67	67
VS1:2	ATCO	0	33	0	0	33	0	0
VS1:3	TECA	100	33	67	0	33	0	0
VS4:1	ARTR	0	0	0	100	100	100	100
VS4:2	CHVI	0	0	0	0	33	33	0
VS4:3	ATCO	0	33	67	100	33	33	33
VG1:1	ARTR	0	33	33	33	0	67	0
VG1:2	CHNA	100	67	67	67	67	67	33
VG1:3	CHNA	100	100	100	100	100	67	67
VG2:1	ARTR	33	0	0	0	100	0	33
VG2:2	SAVE	33	0	0	33	33	0	0
VG2:3	CHNA	100	33	33	67	33	67	33
VG3:1	ARTR	100	100	100	0	100	0	0
VG3:2	ARTR	67	0	33	33	33	0	0
VG3:3	SAVE	33	67	33	67	0	100	33
VJ1:1	ARTR	0	67	0	0	0	0	33
VJ1:2	CHVI	67	33	0	33	33	67	100
VJ1:3	JUOS	33	0	67	33	67	33	100
VJ5:1	ARTR	100	100	100	100	67	100	100
VJ5:2	JUOS	0	33	33	33	0	0	0
VJ5:3	ARTR	0	0	33	33	0	0	0
VR2:2	CHNA	100	100	100	67	100	33	33
VR2:3	CHNA	100	100	100	100	100	67	100
Control	---	0	0	0	0	0	0	0
All Samples		46±45	41±39	46±40	48±39	51±39	39±37	38±39

moisture content were negative. Two explanations are possible. First, because fungi were not measured in April, it is possible that a large spring bloom was missed and that a relatively dormant portion of the annual cycle was measured between June and December. Second, the analytical technique for measuring total fungi, which does not distinguish living from dead hyphae, may have masked true fluctuations in active fungal populations. Work to resolve these questions will continue during 1982.

(3). Levels of microbial activity (respiration and dehydrogenase activity) are not well correlated with total microbial counts. This result is commonly reported in the soils literature and it suggests that: (a) only portions of microbial populations are active at any given time and those portions vary markedly; and/or (b) analytical techniques for soil microbiology are imprecise. Regardless of their cause, the poor correlations suggest that a thorough monitoring program should include measures of both microbial numbers and activities.

(4). Levels of microbial activity were positively correlated with soil moisture, organic matter, and mineral nitrogen contents. It is reasonable to assume that moisture and organic matter are important determinants of microbial activity and these variables should be included in future monitoring programs. In theory, high mineral nitrogen content are results, and not direct determinants, of high microbial activity. Mineral nitrogen fractions will not be measured in 1982, but analyses can be resumed if impacts of oil shale development on nitrogen cycling are suspected.

(5). Microbial activities were correlated with soil pH and Ec. It is not clear at this time whether these are cause and effect relationships

or merely circumstantial associations. Microbial activities may be high in finer soils because they have relatively high moisture contents and not because they have relatively high EC's. Similarly, dehydrogenase activity may be high in soils with relatively low pH's only because those soils have relatively high organic matter contents. Nevertheless, changes in soil pH and EC are potential impacts of oil shale development, and measurements of these parameters will continue.

(6). Textural, chemical, and microbiological characteristics of tract soils do not vary markedly between vegetation types. On the average, there is as much variation within soils of given transects as between soils of different sites. VS-1 and VR-2 soils may be exceptions, but further study is needed to define significant differences. High variabilities within transects may pose problems for detection of future impacts. Relative uniformity in baseline measurements between sites, however, will aid impact detection by establishing parity and easing comparisons between transects that are upwind and downwind from the retort site.

(7). The largest predictable variations in microbiological characteristics of tract soils appear to be seasonal. Further monitoring is required to determine how predictable seasonal fluctuations are, but it seems likely at this point that the number of sampling periods can be reduced to four per year, one in mid-spring, one in late-summer, one in mid-fall, and one in mid-winter.

(8). Surface (0-15 cm) soils on the tracts support active populations of VA mycorrhizal fungi and nitrogen fixing Rhizobium bacteria. As such, they could provide beneficial microbial inocula if used properly in

the revegetation effort. Further studies will be required to determine: (1) impacts of topsoil storage on fungal and bacterial populations; (2) impacts of topsoil dilutions on populations of those microbes; and (3) impacts of underlying processed shale upon microbial populations of respread topsoil.

4.3.4 Reclamation Research Studies

Several new reclamation studies were added for 1981. These included interseeding and interplanting of shrub seedlings in an established shrub community, migration of salts in a processed shale disposal site, root growth in processed shale and initiation of a topsoil storage pile. Results for these continuing studies are discussed in the following sections.

4.3.4.1 Monitoring of Existing Study Sites Each of the existing study sites (Section 6, G-17, G-8, G-3 and Anvil Points), were visited to observe general conditions such as understory weediness, and animal use. From this visit continued usefulness of the plots as long term indicators of reclamation success could be determined. In each situation, the plots were still functional. Fences were intact and no unusual conditions were noted. WRSP's plots at Anvil Points were reviewed for plant survival and growth. The studies monitored included:

- o topsoil-filled trench;
- o plantings in shale, either in basins or flat surface;
- o plantings in shallow furrows filled with soil;
- o demonstration plantings in shale along fences of study areas.

To facilitate comparisons, 1981 results are shown in relation to data from pervious years.

Results with plant survival percentage and height in the topsoil filled trench at Anvil Points appear to validate the hypothesis that plants can be established and will survive in a topsoil filled trench in an oil shale disposal pile (Figure 4.3-6). The only change in plant survival from 1980 and 1981 was a loss of one prostrate kochia (Kochia prostrata) plant in the north trench and one in the south trench. One plant of shadscale (Atriplex confertifolia) in the south trench also died. The current status of plant survival of the seven species planted at Anvil Points in the spring of 1978 are as follows: fourwing saltbush, 100%; shadscale, 85%; cuneate saltbush (Atriplex cuneata), 95%; western wheatgrass (Agropyron smithii), 100%; greasewood, 100%; prostrate kochia, 50%; and seepweed (Suaeda spp), 50% (Table 4.3-15). It appears that these plants have reached a stable condition, although increases in crown diameter have been noted.

Survival of plants that were planted directly into shale at Anvil Points either in basins or on the flat surface, has been of importance in validating the hypothesis that native halophytes could survive direct planting in processed oil shale (Figure 4.3-7). Not all species have survived satisfactorily (Table 4.3-16). In the basin plantings, the two species that have been the least successful are shadscale and seepweed. In the flat plantings, a high, overall survival has been observed for the six species. The data, as well as field observations, suggest that the basin is not as effective as a flat planting. This result suggests some possible adverse effects from potential harvesting salts accumulation

Figure 4.3-6 Establishment and survival of plants in topsoil filled trench at Anvil Points, Colorado, June 1981.

Table 4.3-15. Plant survival and growth in the north and south soil trenches on four observation dates at Anvil Points, Colorado.

Species	North Trench						South Trench					
	1979 July		1980 June		1981 June		1979 July		1980 June		1981 June	
	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm
Fourwing saltbush	100	24	100	30	100	55	100	27	100	36	100	56
Shadscale	100	7	90	9	90	16	100	6	90	9	80	15
Cuneate saltbush	100	10	90	10	90	17	100	15	100	18	100	22
Western wheatgrass	100	24	100	10	100	15	100	22	100	9	100	15
Greasewood	100	21	100	33	100	55	100	25	100	36	100	63
Prostrate kochia	50	15	50	16	40	33	67	30	67	19	60	34
Seepweed	100	16	40	16	40	24	80	17	60	23	60	24

Date of planting - April 26, 1979

Data are the average of ten plants except for Kochia which is the average of six plants, and seepweed of 5 plants.

Figure 4.3-7 Exclosure site at Anvil Points showing survival of transplanted shrubs directly into processed shale. Photo taken in October 1981.

Table 4.3-16. Comparison in plant survival of six species planted in basins for water harvesting or level with soil material.

Species	Basin Planting						Flat Planting					
	1979 July		1980 June		1981 June		1979 July		1980 June		1981 June	
	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm
Fourwing saltbush	100	27	100	34	100	63	100	28	100	36	100	60
Shadscale	100	5	20	9	0	0	100	8	100	9	80	11
Cuneate saltbush	100	9	80	12	60	13	100	13	100	15	100	21
Western wheatgrass	100	22	80	23	80	50	100	20	100	28	100	32
Greasewood	100	18	100	28	100	47	100	18	100	29	100	40
Seepweed	100	31	40	35	20	45	100	17	60	23	60	27

Date of planting - April 26, 1979

These were planted directly in the processed shale pile except for the small amount of soil material used in the various containers.

into the basins. Inasmuch as there is no significant amount of weedy vegetation around the flat plantings, there is no loss of soil water from competition which has been shown to be a problem in other studies. The influence of the shale on plant growth (height) may be seen by comparing the average height of fourwing saltbush and greasewood in shale (62 cm and 44 cm, respectively) with their heights in the topsoil filled trench (55 cm and 59 cm, respectively). Significant differences or trends are not apparent.

Plant survival and growth in soil enriched microenvironments appears to be equally as successful as in the soil filled trenches or direct planting on shale. Plant survival ranged from 80% to 100% in 1981 (Table 4.3-17). Plant heights of the five species appears to have stabilized at values consistent with their natural stature under field conditions. One of the advantages of the small furrows was that moisture was concentrated for infiltration without increasing the concentration of salt. Salt did not appear to concentrate in the vicinity of the transplants. Further observations and soil/spoil sampling are necessary to validate any conclusions regarding the advantages of small furrows with and without soil in them.

In 1978 when the WRSP plant studies were initiated at the Anvil Points study site, six species of container-grown plants were set out as a border inside the security fence. The survival and growth (height) of these plants has been followed to provide further information on the feasibility of growing plants in shale. The plants have received only a liquid fertilizer solution (1 liter) each spring. Results indicate a high survival rate for fourwing saltbush, gardner saltbush (Atriplex

Table 4.3-17. Plant survival and growth at five observation dates over three years under soil-shale microenvironment with the container-grown transplants planted in shallow furrows filled with soil at Anvil Points, Colorado.

Species	Survival					Plant Height				
	1979 July	1979 Sept	1980 June	1980 Oct	1981 June	1979 July	1979 Sept	1980 June	1980 Oct	1981 June
	%	%	%	%	%	cm	cm	cm	cm	cm
Fourwing saltbush	100	100	100	100	80	22	26	26	41	42
Shadscale	100	100	100	100	100	6	6	10	9	12
Cuneate saltbush	100	100	100	100	100	9	10	11	15	10
Western wheatgrass	100	100	100	100	100	18	13	19	18	25
Mat saltbush (Atriplex corrugata)	100	100	100	100	80	6	9	8	7	5

Date of planting - April 26, 1979

gardneri), siberian salt tree (Halimodendron halodendron), and greasewood; a medium survival rate for shadscale; and failure for big sagebrush (Table 4.3-18). The poor adaptation of big sagebrush is not unexpected because of its adaptation to upland sites and more neutral (pH) soils. The other species add confidence to the results obtained in the replicated studies within the research area.

4.3.4.2 Migration of Salts in Processed Shale Data are being collected to test the hypothesis that salts will not accumulate to a toxic concentration in the root zone of a topsoil-filled trench in a processed oil shale disposal pile. To follow general trends in salt movement and accumulation, soil and oil shale samples were taken at various depths and locations (Figure 4.3-8) in June and October at the Anvil Points study site. These samples were analyzed for pH and electrical conductivity (EC). A 1:1 solution was used to determine EC and a saturated paste was used to determine pH.

Several important points emerge from an inspection of the data relative to plant survival and salt tolerance. The first point is that in the topsoil the pH and EC values do not exceed the limits of tolerance observed for the halophytic species planted in the soil (Table 4.3-19).

Table 4.3-19. Salinity and pH of topsoil and shale. Anvil Points study site.

Sample Location	pH		EC	
	June	October	June	October
0-1" soil	7.90 ± 0.10	7.84 ± 0.17	4.40 ± 2.3	3.06 ± 2.2
6" soil	7.41 ∓ 0.49	7.69 ∓ 0.13	2.00 ∓ 0.06	2.93 ∓ 1.7
12" soil	7.52 ∓ 0.41	7.63 ∓ 0.09	3.00 ∓ 0.40	4.36 ∓ 0.9
18" soil	7.61 ∓ 0.08	7.89 ∓ 0.28	3.7 ∓ 1.9	7.49 ∓ 3.7
20" shale	8.14 ∓ 0.11	8.51 ∓ 0.04	6.20 ∓ 1.2	12.5 ∓ 1.4
0-1 interface shale/soil	8.08 ± 4.0	8.70 ± 0.24	>7.20 ± 6.9	17.9 +11.5
6" shale	8.11 ∓ 0.10	8.38 ∓ 0.24	4.8 ∓ 2.3	16.0 ∓ 3.1

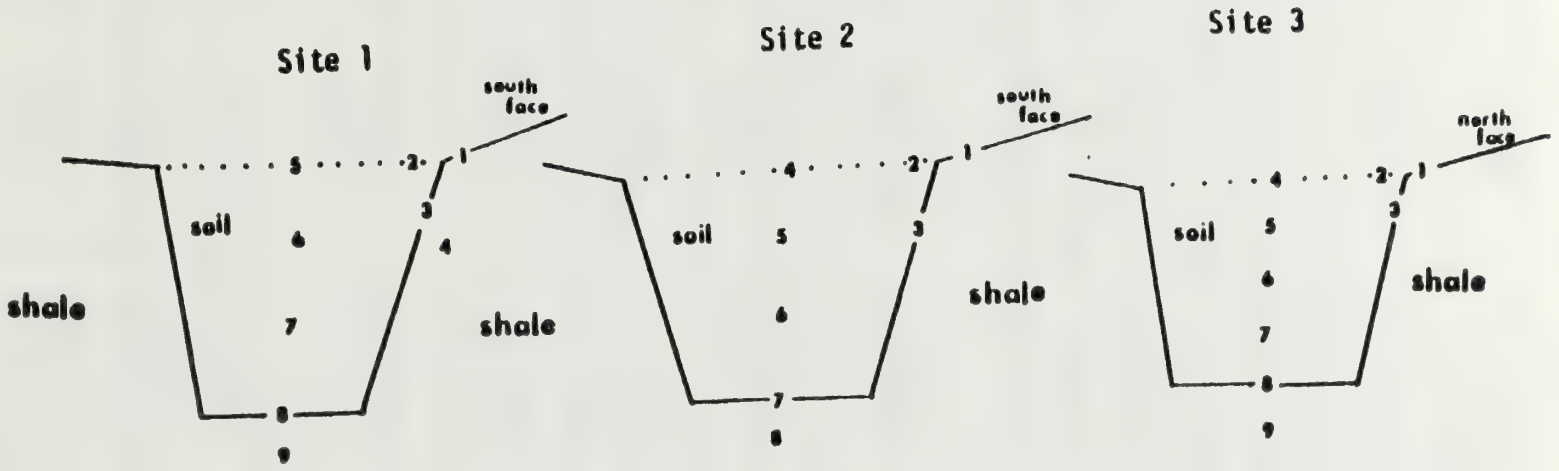
Table 4.3-18. Survival over five observation dates over three years of a miscellaneous demonstration planting along the east and south fences within the exclosure at Anvil Points, Colorado.

Species	East Fence										South Fence									
	Plants Planted	1979 July		1979 Sept		1980 June		1980 Oct		1981 June		Plants Planted	1979 July		1979 Sept		1980 June		1980 Oct		1981 June	
	No.	%	cm	%	cm	%	cm	%	cm	%	cm	No.	%	cm	%	cm	%	cm	%	cm	%	cm
Fourwing saltbush	3	100	19	100	24	100	24	100	40	100	34	6	83	27	83	32	67	29	67	48	67	48
Shadscale	1	100	14	100	14	100	15	100	16	100	17	4	75	15	57	14	75	13	75	12	50	12
Gardner saltbush	2	100	7	100	7	100	11	100	9	100	7.5											
Big sagebrush	1	100	14	100	16	100	25	100	23	0	0											
Greasewood	4	100	19	100	26	100	26	100	32	100	25.8	6	100	19	100	23	100	19	100	27	100	24
Siberian salt tree	1	100	15	100	14	100	12	100	16	100	7	1	100	23	100	32	100	30	100	30	100	39

Planting - south fence, March 27, 1979
- east fence, April 29, 1979

The plants were grown in a greenhouse study initiated in December 1975 where the plants were grown either in processed shale or in regular soil.

Figure 4.3-8. Location of soil/shale sampling sites in topsoil-filled trench.



The second point is that soil in the bottom of the trench just above the shale appears to be increasing in salt content. Further monitoring is obviously necessary to determine if this trend is real and will continue. A third point is that salts are being picked up in runoff water harvested from the short slopes adjacent to the topsoil-filled trench. These salts are being deposited on the soil surface near the edge of the trench (0-1" interface soil/shale). However, the salts are not moving into the rest of the topsoil trench. A fourth point is that the main body of topsoil in the trench remains low in salts (low EC) and has a pH range of 7.7, well within the tolerances of the species planted there.

Soil in the oil shale trench was also analyzed for sodium, calcium, magnesium, molybdenum, cadium, arsenic, boron, and mercury (Table 4.3-20). As expected, the salts Na, Ca, and Mg were high in shale samples. Values for these elements were lower in soil and within the tolerance range of the species planted in the soil trench. Additional samples over time will be needed to make a proper interpretation.

The differences in pH among the samples and between the black and white sample groups were not significant. The seven-fold difference in EC between black and white samples, however was very dramatic. The biological significance of these high concentrations of salts in areas where capillary rise and evaporation have created high salt contents is great. EC levels of the white shale exceed the tolerance of most organisms (seeds, etc.) to survive. Therefore, a management strategy is important to prevent salt concentration. In another section, a brief discussion of seed germination and weed invasion will be discussed.

Table 4.3-20. Values in pH, EC and elemental content of salinized and non-salinized surfaces of a processed oil shale disposal pile, October 1981.

Description of Site	pH[1]	EC[2]	Element: PPM Na	Ca	Mg	Mo**	Cd	As	B*	PPB Hg
Black surface										
Oil shale sample #1	8.55	11.04	20400	111350	37000	25	<2.5	45.0	50	196
Oil shale sample #2	8.53	9.01	20100	104650	36500	25	<2.5	40.0	50	210
Oil shale sample #3	8.45	6.24	18650	104450	37700	27	<2.5	45.0	50	250
Oil shale sample #4	8.22	.4.24	18800	106450	35850	25	<2.5	40.0	50	195
White surface										
Oil shale sample #1	8.82	55.9	58350	85000	31400	25	<2.5	35.0	50	140
Oil shale sample #2	8.74	53.4	32750	104350	32000	25	<2.5	35.0	50	200
Oil shale sample #3	8.73	54.4	45450	95400	30750	25	<2.5	30.0	50	160
Oil shale sample #4	8.72	81.8	109650	71650	23550	25	<2.5	40.0	50	115

1. pH - saturated solution process
2. EC - 1:1 solution process, in mmhos per cm^3

* All B is <50

** All mO is <25 except Oil shale pile 3, Black Surface, which has 27

PPM - parts per million; PPB - parts per billion

Na - Sodium
Ca - Calcium
Mg - Magnesium
Mo - Molybdenum
Cd - Cadmium
As - Arsenic
B - Boron
Hg - Mercury
SO_4 - Sulfate

4.3.4.3 Root Growth in Processed Shale In order to determine if root growth was limited or inhibited while growing in processed shale, roots of five western wheatgrass plants growing in the topsoil-filled trench at the Anvil Points study site were excavated during June 1981. The plants appeared to have some of their roots growing in the shale because of their position in a shallow soil layer overlying the adjacent shale.

Observations showed that roots were growing easily in the processed shale from each of the western wheatgrass plants (Figures 4.3-9a, 4.3-9b). A large healthy rhizome was observed growing about 30 cm (one foot) into the shale. Intact root systems growing in both shale and soil were returned to Native Plants laboratories where they were observed under high power binocular microscope. No apparent differences were noted in root dimensions, characteristics, or root hairs between roots growing in soil and those growing in processed shale. From other observations we have made root growth in shale will proceed if there is sufficient water to keep the shale moist and if salts do not concentrate beyond a point of tolerance. The latter point has not been clearly shown at the present time.

Rather than make a larger disturbance to the root systems in September 1981, additional studies will be made in the spring, 1982 which biologically parallel the spring, 1981 study.

4.2.4.3 Plants Invading Processed Shale Disposal Sites This study is intended to gather data useful to the development of an operational reclamation program. A temporary weed cover may be more economical than

Figure 4.3-9a Western wheatgrass growing in topsoil-filled trench. Note the emergence of tillers in oil shale upslope.

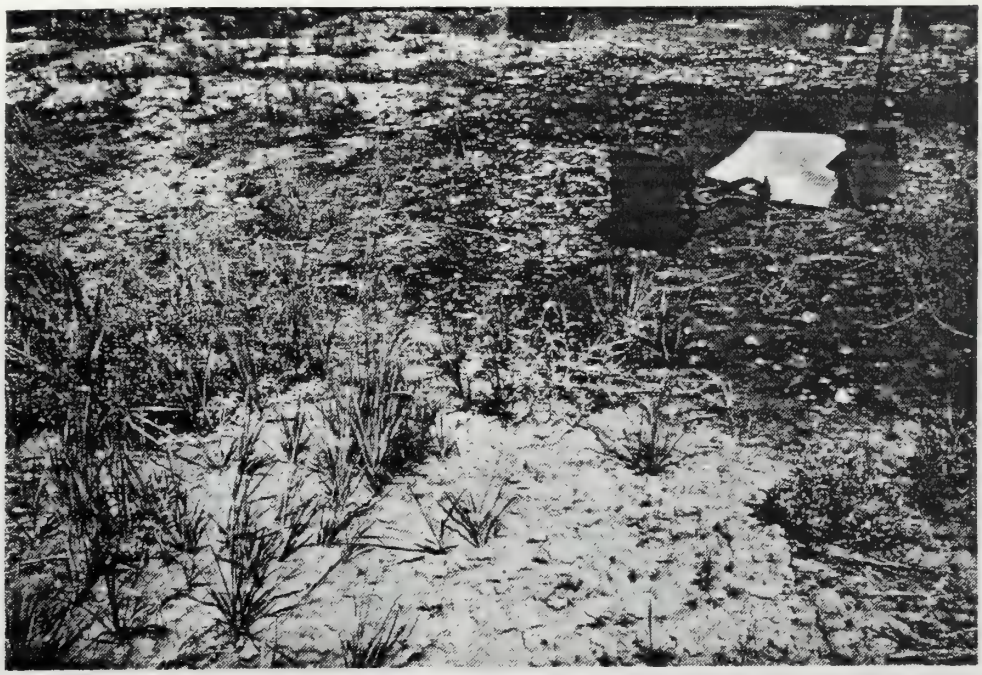


Figure 4.3-9b Western wheatgrass roots growing in processed shale. Plants were obtained from the reclamation study site on a processed oil shale disposal pile at Anvil Points, Colorado. Note the large healthy thizome growing into processed shale.

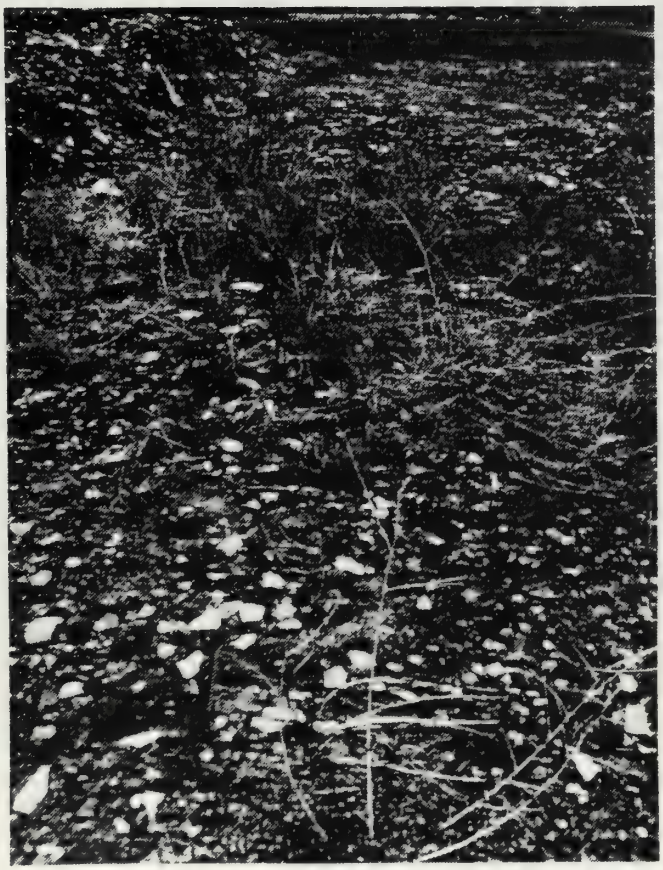
a surface stabilizing material or extensive sprinkling. It appears that numerous annual weedy invader species are able to colonize harsh sites, such as processed shale, without the benefit of mycorrhizae. It has been observed that species invading the oil shale disposal pile at Anvil Points include Russian thistle, halogeton, weedy kochia (Kochia scoparia), and white milkweed (Mentzelia albicaulis).

The invasion of these weeds onto the northern half of the processed shale disposal pile at Anvil Points has been observed since 1977. The first species to colonize small depressions and shaded microsites was Russian thistle. Subsequently other species followed in areas free of capillary rise salt deposition. From the preliminary data regarding salt content of oil shale surfaces, those areas free of capillary salt deposit can sustain some seedlings of invading weeds. The benefits of subsequent litter deposits cannot be overlooked in the process of plant succession and surface stability.

In June 1981 photographs were taken along three transects marked with metal stakes (Figure 4.3-10a,b,c). These same transects will be rephotographed in subsequent years. Cover estimates along the transects indicated an average of 65% cover.

4.3.4.4 Interseeding/Interplanting Existing Shrub Vegetation As a means of increasing the wildlife carrying capacity of existing shrub-dominated vegetation, interseeding and/or interplanting has been suggested. A study was established in October 1981 to test the hypothesis that scattered inter-plantings of container grown plants could survive and increase community diversity and productivity. A corollary

Figure 4.3-10a, b, c Transects of invading annual weedy species.



hypothesis of the study tested direct seeding (drilled and broadcasted) to increase diversity and productivity.

The study was established inside the Section 6 research enclosure as shown in Figure 4.3-11 and 4.3-12. Four replications, two in sites with minimal understory plants and two in areas with dense understory of cheatgrass, were seeded and transplanted. The species transplanted included gardner saltbush (ATGA), fourwing saltbush (ATCA), and rubber rabbitbrush (CHNA), and Wyoming big sagebrush (Artemisia tridentata wyomingensis, ARTRW). Plants were supplied from standard nursery Tubepak stock from NPI and were at least six months old. Plants were inter-planted into the existing shrub community on a 1-meter spacing within and between rows. Each row contained 13 plants.

The direct seeding portion of the study was accomplished by broad-cast seeding followed by raking to simulate a chain drag. Drill seeding was accomplished with a hand-push single furrow seeder. Because of the small size of the plot area, larger equipment such as a tractor drawn inter-seeder would have been impractical. Seeding rates were calculated on a Pure Live Seed (PLS) basis. The seed mix was composed of 75% shrub and 25% grass seeds (Table 4.3-21).

Success of the seeding and interplanting will need to be monitored for a 3-year period to determine the best species and methods. A light rain fell just as the plots were being planted in October 1981, thus, helping to settle soil around seeds and plants.

4.3.4.5 Initiation of Topsoil Stockpile Many questions have been raised concerning the biological effects of storing topsoil while

Figure 4.3-11. Section 6 - Interplanting and Seeding Scheme

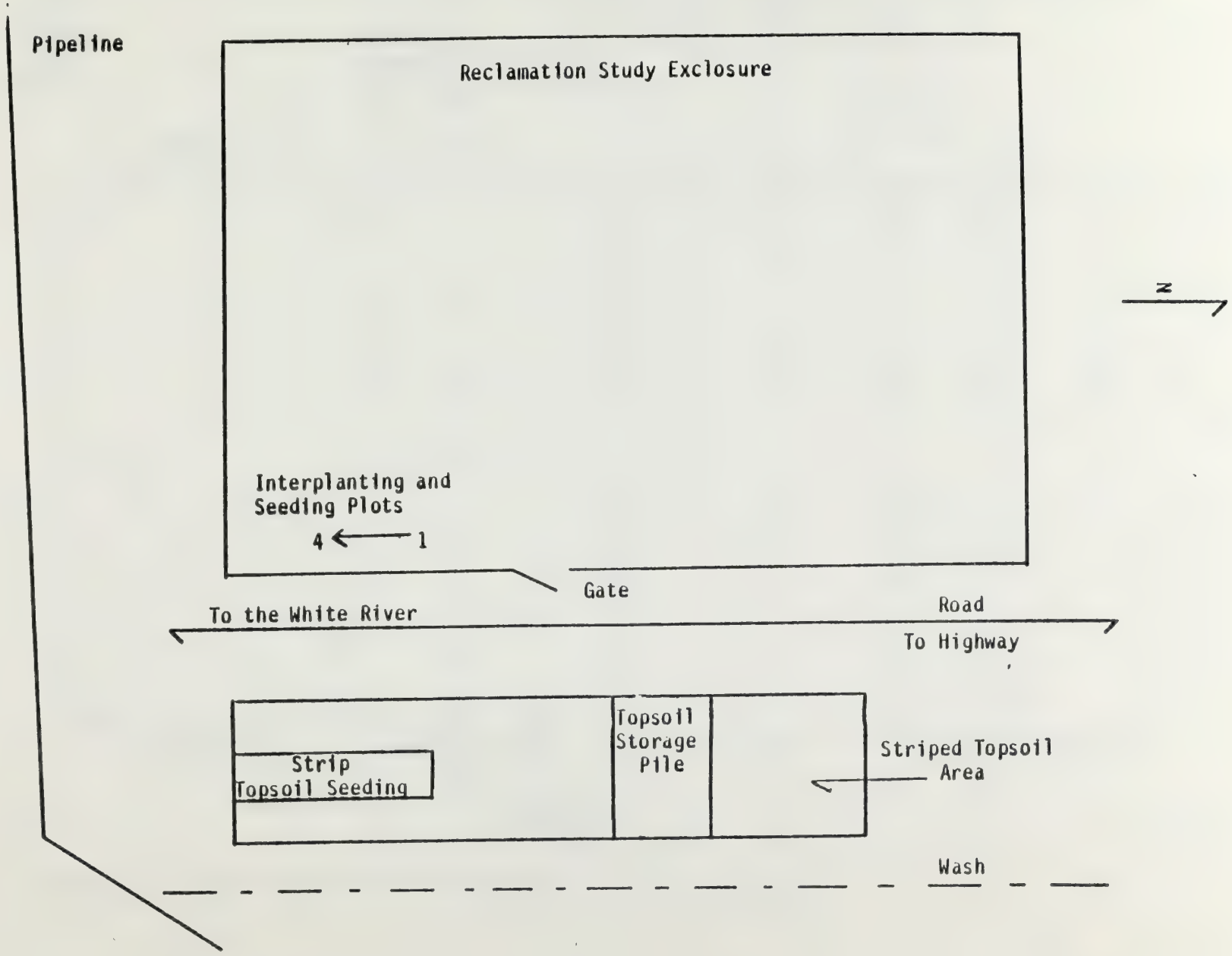
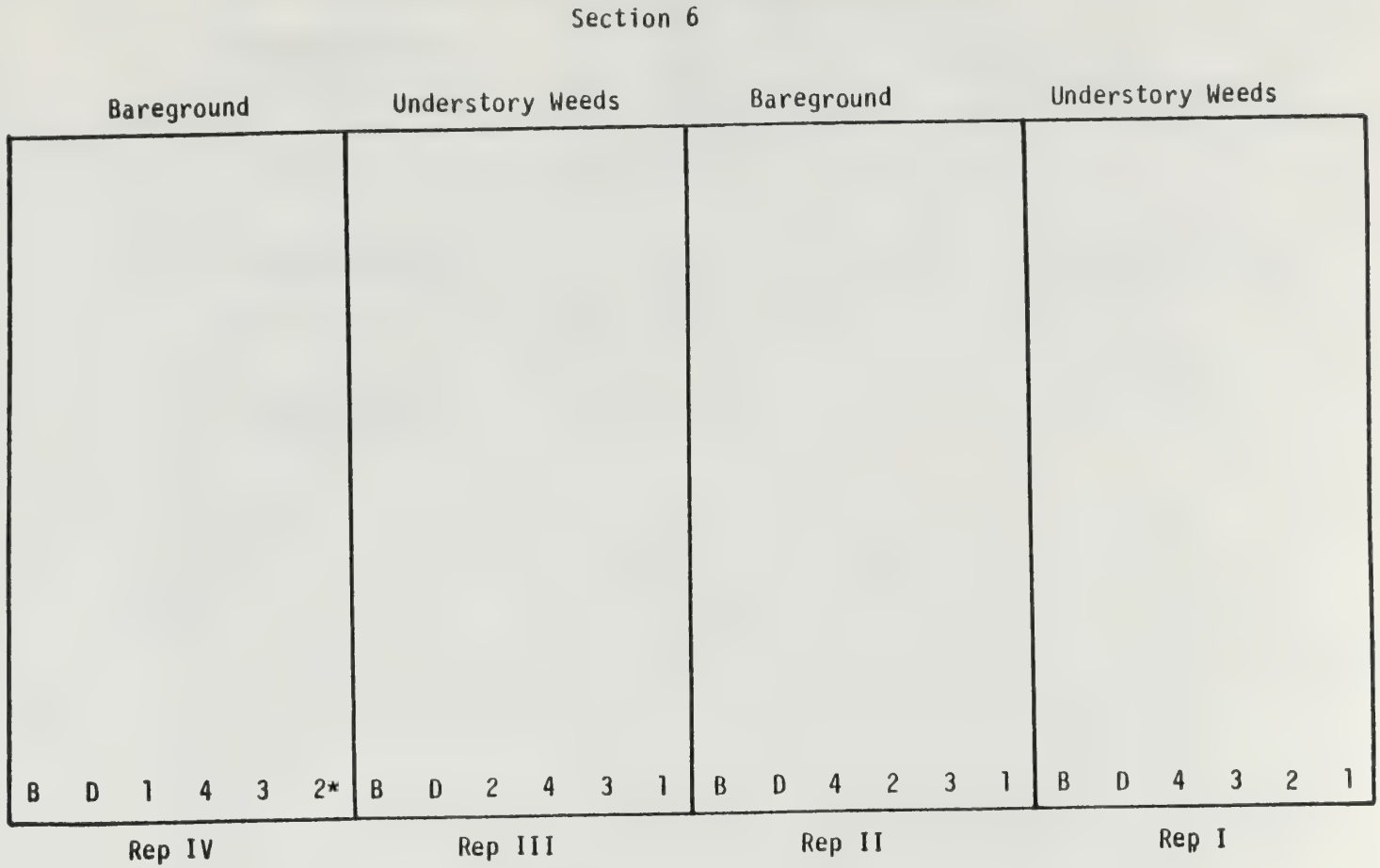


Figure 4.3-12. Interplanting and Interseeding of Shrubs and Seeds.



All plants on ≈ 1 m centers
13 outplants/species
*6 outplants

Species
1 - ATGA
2 - ATCA
3 - CHNA
4 - ARTRW
D - Drill seed (rate: 22 lbs/acre PLS @ 1/2" depth), 3 rows - 4" interval
B - Broadcast seed (rate: 22 lbs/acre PLS, raked in)

N →

Species Seeded

ELJU, HIJA } Grass 25%

ARTRW, CHVU, ATGA } Shrubs 75%

Table 4.3-21. Seed mix for interseeding shrublands to increase carrying capacity. Section 6 study site, October 1981.

SEED CALCULATIONS PER PLOT*

Species	Seeds/lb. PLS	Total PLS Needed	PLS Rating %	% Seed in Mix 1.	Lbs./Plot
Russian wildrye (*Elymus junceus*)	175,000	18,000	90.84	7	0.04
Galleta (*Hilaria jamesii*)	159,000	18,000	76.19	10	0.05
Wyoming big sagebrush	2,575,940	27,000	8.41	7	0.04
Douglas rabbitbrush	782,000	27,000	45.50	5	0.03
Gardner saltbush	111,450	27,000	39.42	37	0.21
Greasewood	119,744	27,000	37.88	35	0.20
				Total	0.57

*Based on 30 PLS/sq. ft. and 1,600 sq. ft. research plots equivalent to 15.5 lbs/acre.

1. Application rate: 25% grasses and 75% shrub.

awaiting its replacement over spoil materials. Burial of seeds and reduced oxygen availability to soil microorganisms are two major adverse effects created by storage. Another problem involves stabilization of the surface of the pile.

To provide a test site for study of topsoil microbiology and stabilization, a topsoil pile was constructed just east of the Section 6 study site. A chemical analysis was run on two samples from the pile (Table 4.3-22).

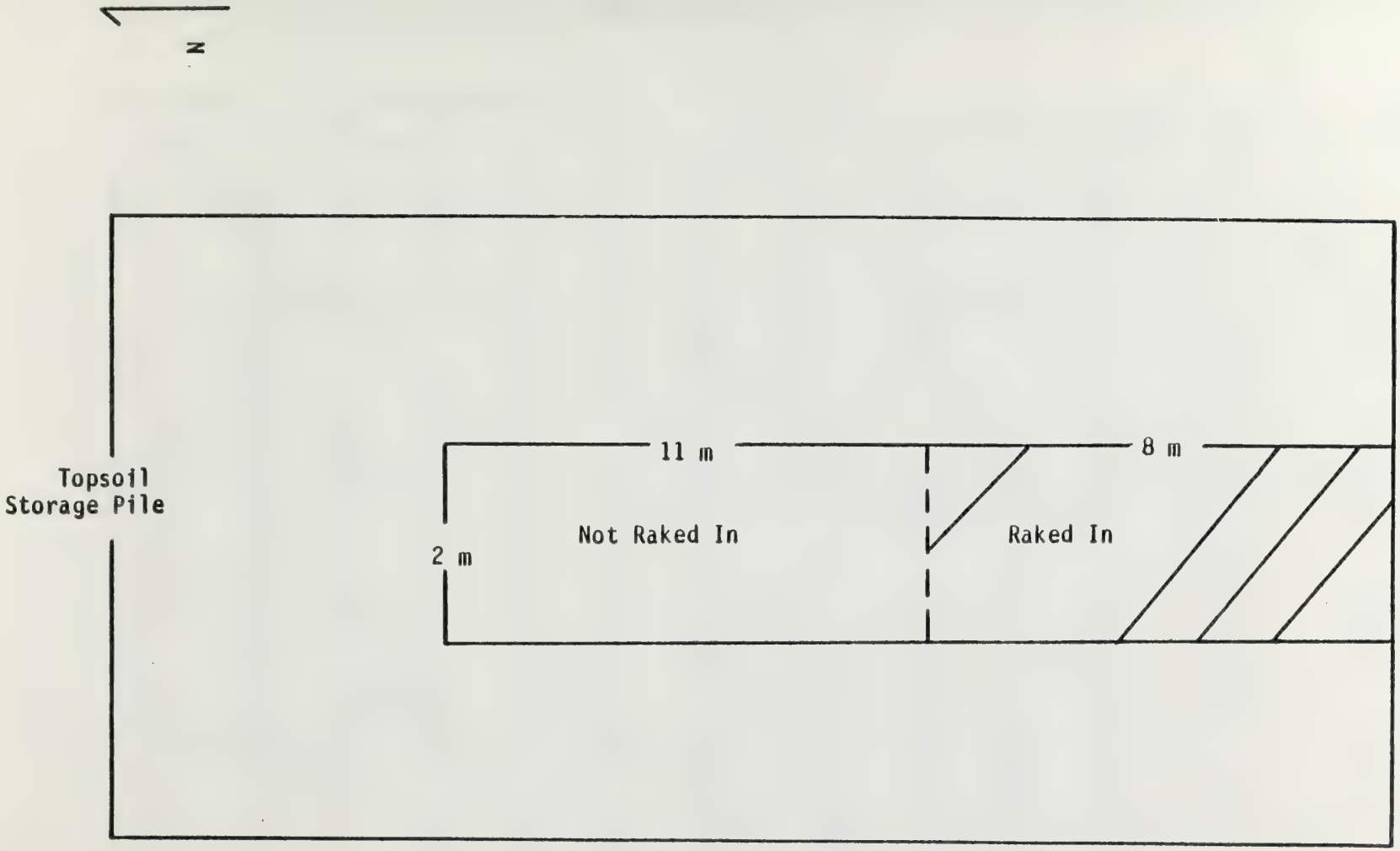
Table 4.3-22 Soil analysis of topsoil storage pile. Section 6 study site.

			Elements							
Topsoil Pile (Section 6)	pH	EC	Na	Cd	Mg	Mo	Cd	As	Bo	Hg
South face 10/81	8.04		30350	32950	12100	25	<2.5	<25.0	50	20
Top	8.05	0.49	27750	29600	11550	25	<2.5	<25.0	50	15
North face 10/81	8.10	0.65	29850	29250	11550	25	<2.5	<25.0	50	25

A portion of the pile was seeded and one half of the seeded area was raked to obtain seed coverage. The species seeded were the same as those used in the interseeding study (Figure 4.3-13).

A portion of the area cleared for topsoil collection was also seeded to demonstrate seeding for revegetation of disturbed sites where no competing vegetation or weed seed existed at the time of seeding (Figure 4.3-14). Results will be repeated in the 1982 progress report.

Figure 4.3-13. Tosposil Storage Pile* Strip: Seeding Trial - Cyclone Broadcast



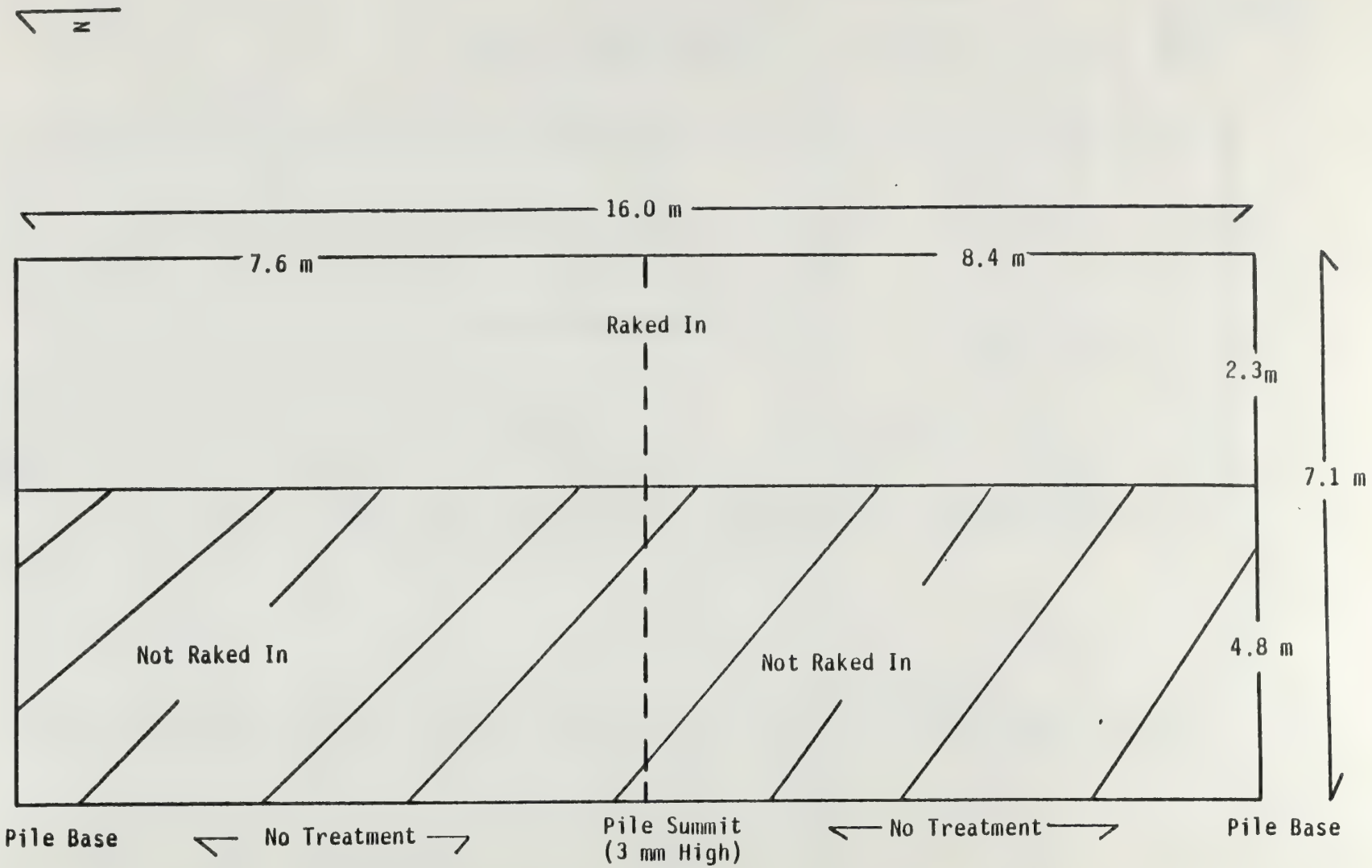
Species Seeded: ELJU, HIJA } Grasses 25%

ARTRW, CHVI, ATGA, SAVE } Shrubs 75%

Area: $38m^2$
0.0094 Acres
11.1 lbs/Acre

*Section 6

Figure 4.3-14. Topsoil Storage Pile*: Seeding Trial - Cyclone Broadcast



Species Seeded: ELJU, HIJA } Grasses 25%
ARTRW, CHVI, ATGA } Shrubs 75%

Area: 112 s_2m
0.03 Acres
17.0 lbs/Acre

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TERRESTRIAL FAUNA

4.4 TERRESTRIAL FAUNA

This section is a description and analysis of all data collected on amphibians, reptiles, birds, mammals, soil invertebrates and terrestrial invertebrates from 1975 through 1981 and, as such, is a comprehensive baseline of the terrestrial fauna on Tracts Ua and Ub. This section focuses on the patterns of change over seasons, between years, and among habitats with emphasis on identifying causes of change. These causes are of prime importance in future monitoring so that man-induced changes can be distinguished from those that occur naturally.

This report is divided into six sections, as follows; soil invertebrates, terrestrial invertebrates, amphibians and reptiles, birds, mammals, and special studies. Figure 4.4-1 shows the locations of the terrestrial fauna monitoring sites.

The WRSP terrestrial fauna monitoring program is conducted by Bio Resources, Inc. of Logan, Utah under the direction of Dr. C. Val Grant.

4.4.1 Objectives

The major objective of the terrestrial fauna monitoring program is to provide a data base which will allow WRSP to determine if mining and processing of oil shale and related activities significantly affect the structure and function of the local terrestrial ecosystem. Thus, there are three major goals:

- To determine if there is a departure from "normal," defined as ambient conditions during the seven year baseline period.

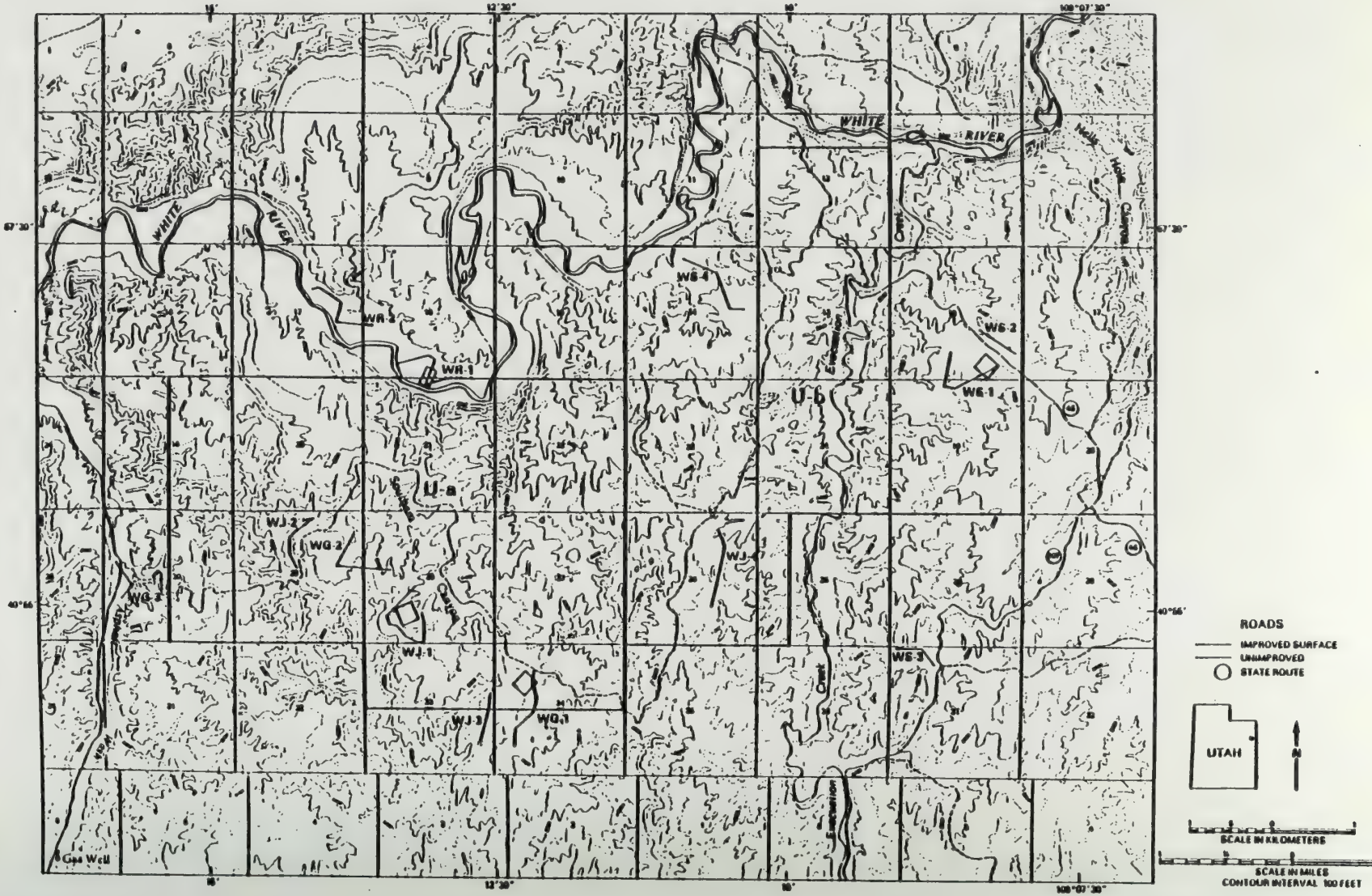

Figure 4.4-1

SAMPLING LOCATION MAP

- To discover if this departure is caused by man's activities or if it is related to natural environmental changes.
- To evaluate the success of reclamation efforts in terms of returning disturbed areas to their original conditions.

4.4.2 General Methods

To avoid repetition, sampling procedures common to all terrestrial groups are described here. Those procedures employed with one or only a few taxa are described at the beginning of their respective sections.

Flushing Transects - Line transects were used to determine the density of reptiles, birds, and diurnal mammals. In most years, the equivalent of two 1 km transects were walked in each habitat type in each of five months (February, April, June, August, and October). During each sampling session the transects were walked on five consecutive days. Just prior to walking each transect, the ambient temperature (°C), wind speed and cloud cover (%) were recorded. All vertebrates seen or heard from the transect were identified and for those seen, the number, activity, substrate and perpendicular distance from the transect line were recorded.

Species Diversity - Diversity was calculated using the Shannon-Weiner Index (Shannon 1948):

$$H' = \Sigma P_i \ln P_i$$

where P_i is the proportion of individuals (of observation) in each species (or group) and H' is diversity. Evenness was calculated as $J'=H'/H_{max}$ where H'_{max} is the natural log of the number of species. Species richness refers to the number of species in a

particular sample or group of samples.

Vegetation Structure - Three measures of vegetation structure were determined: (1) shrub cover; (2) shrub volume; and (3) foliage-height diversity. For the cover and volume measurements, ten points 100 m apart were selected along each flushing transect. A circular plot centered on each point was established. The radius of each plot varied to include at least ten shrubs. Each shrub was identified and measured (height, least width, greatest width). Cover and foliage volume were calculated using the following formulae:

Cover - 3.1416 (least diameter x greatest diameter/4)

Foliage Volume - 1.333 x cover (height/2)

Foliage profiles were determined as follows: at approximately 10 m intervals along each flushing transect, a pole calibrated in half meters (0 to 600 cm) was held vertically. The height at which perennial vegetation contacted the pole was recorded. All foliage measurements in each habitat per pooled, resulting in approximately 400 measurements on Greasewood, Juniper and Shadscale and 200 measurements on Riparian. Foliage-height diversity was calculated based on four height classes: 0-50 cm, 50-200 cm, 200-400 cm and >400 cm. These strata roughly correspond to low shrubs, medium shrubs, high shrubs and juniper, and trees (cottonwood).

Similarity Indices - Similarity was calculated using the Bray-Curtis coefficient (Motyka et al. 1950). This coefficient is a weighted index of species composition. Three types of weighting factors were used: (1) absolute abundance; (2) biomass; and (3) relative abundance.

4.4.3 Soil Invertebrates

4.4.3.1 Introduction The significance of soil-litter fauna in monitoring ecosystem changes in cold deserts is largely unknown. Further, the importance of this fauna as a component of reclamation of disturbed sites requires evaluation. The abundance and diversity of the soil-invertebrates are necesary components in the decomposition of matter in an ecosystem (Crossley 1977). These fauna, especially the arthropods and nematodes, serve as a regulator of decomposition in terrestrial systems (Santos et al. 1981). Specifically, soil animals accelerate (or delay) nutrient release and organic matter reduction, directly and indirectly. Direct effects include feeding on organic debris and predation on associated microflora, while indirect effects include channeling and mixing of the soil, improving quality of substrate for the microflora, inoculation of organic debris with microbes, and prevention or reversal of senescence of microbial populations.

Loss of these effects would significantly alter primary productivity. The presence or absence of these invertebrates provides a measure of success in determining pedogenesis on disturbed lands and indicate whether amendments are needed for revegetation. In order to determine the status of soil invertebrates in an undisturbed system, a study was initiated in April, 1981 to measure this microscopic fauna's taxonomic composition, spatial distribution and seasonal activity, and abundance. These measures were taken in conjunction, both temporal and spatial, with work on soil nutrients and microflora discussed in Section 4.3.

4.4.3.2 Methods Twelve soil samples were collected under big sagebrush (Artemisia tridentata) along eight line transects (see General Methods). The first sample was collected at an arbitrary point near one end of the transect which varied with each collection date. Thereafter, collections were taken at intervals of 90 paces. Each shrub sampled was flagged. Samples were taken with a coring device with four cores taken equidistantly around the shrub. Each shrub was measured for shrub volume. Soil temperatures were taken on the exposed and shaded sides of the shrub. This sampling procedure was repeated in April, June, August, October and December, 1981.

Samples were maintained at 4°C to minimize biotic and moisture changes. A sample was thoroughly mixed until it became homogenous. Two extractions were done on each sample - one for nematodes and one for arthropods.

For both nematodes and arthropods, abundance was expressed as total individuals per cm^2 of surface area. Species richness and species diversity were also calculated.

4.4.3.3 Results and Discussion Table 4.4-1 is a taxonomic listing of the organisms and their trophic positions. Approximately 30 species of nematodes, 50 species of mites (arthropods), and 28 species of insects were collected. The organisms have been assigned to Family by recognizable morphology, as it is currently impossible to ascribe specific or even generic names to many of the soil invertebrates.

Several groups of invertebrates are conspicuous by their absence: Gastropoda, Isopoda, Diploda, Dictyoptera, and Isoptera. The latter groups play a very significant role in the hot deserts but they

Table 4.4-1. Taxonomic composition of soil invertebrates collected during 1981 in four habitats on the Utah Oil Shale Tracts, Ua and Ub, Uinta County, Utah.

Taxa	Trophic Position
Nematoda - nematodes	
Tylenchida	fungivorous/herbivorous
Tylenchoidea	
Aphelenchoidea	
Dorylaimida	microbivorous
Rhabditida	bactivorous/carnivorous
Arthropoda	
Chilopoda - centipedes	carnivorous
Geophilomorpha	
Arachnida	
Solpugida - sun scropions	carnivorous
Eremobatidae	
Pseudoscorpionida - pseudoscorpions	carnivorous
Scorpionida - scorpions	carnivorous
Vejovidae	
Araneida - spiders	carnivorous
Acarida - mites	
Prostigmata	carnivorous
Tydeidae	
Paratydeidae	
Bdellidae	
Pyemotidae	
Tetranychidae	
Linotetranidae	
Caeculidae	
Pseudocheylidae	
Tenerifiidae	
Mesostigmata	carnivorous
Astigmata	detritivorous
Oribatida	detritivorous
Ctenacaroidae	
Gymnodamaeoidea	
Liacaroidea	
Oribatuloidea	
Galumnoidea	
Insects	
Collembola - springtails	detritivorous
Isotomidae	
Poduridae	
Diplura	detritivorous
Anajapygidae	
Psocoptera - booklice	detritivorous
Thysanoptera - thrips	fungivorous
Phlaeothripidae - wingless thrips	
Coleoptera - beetles	carnivorous/detritivorous
Hymenoptera	
Formicidae - ants	herbivorous

apparently are not adapted to conditions in the cold deserts.

While hot deserts are rather harsh habitats for soil invertebrates, the cold deserts, e.g., the Uinta Basin, are in some ways harsher because of periods of winter freezing. Further, the primary input of moisture is during the colder months. However, even under such conditions a diverse soil microfauna was present.

Table 4.4-2 presents the daytime maximum and minimum soil temperatures taken during sample collection. The maximum of 60°C in August is above the lethal point for most animals. The total range of 64°C is

Table 4.4-2. Maximum and minimum soil temperature, °C.

Month	Maximum Temperature	Minimum Temperature
April	38	10
June	52	18
August	60	15
October	22	9
December	14	-4

extreme for most organisms. The associated summer drought is also extreme with near surface soil-moisture essentially zero (Fig. 4.4-2). Nematodes normally require a film or liquid water for movement and feeding. They avoid dry summer conditions by entering a state of crypto- or anhydro-biosis in which they reduce their respiration almost to zero. Many nematodes may survive in this state for years (Freckman 1978). Within minutes of an input of moisture, encysted nematodes may revive and become active. Some arthropods may enter a similar state, but in the

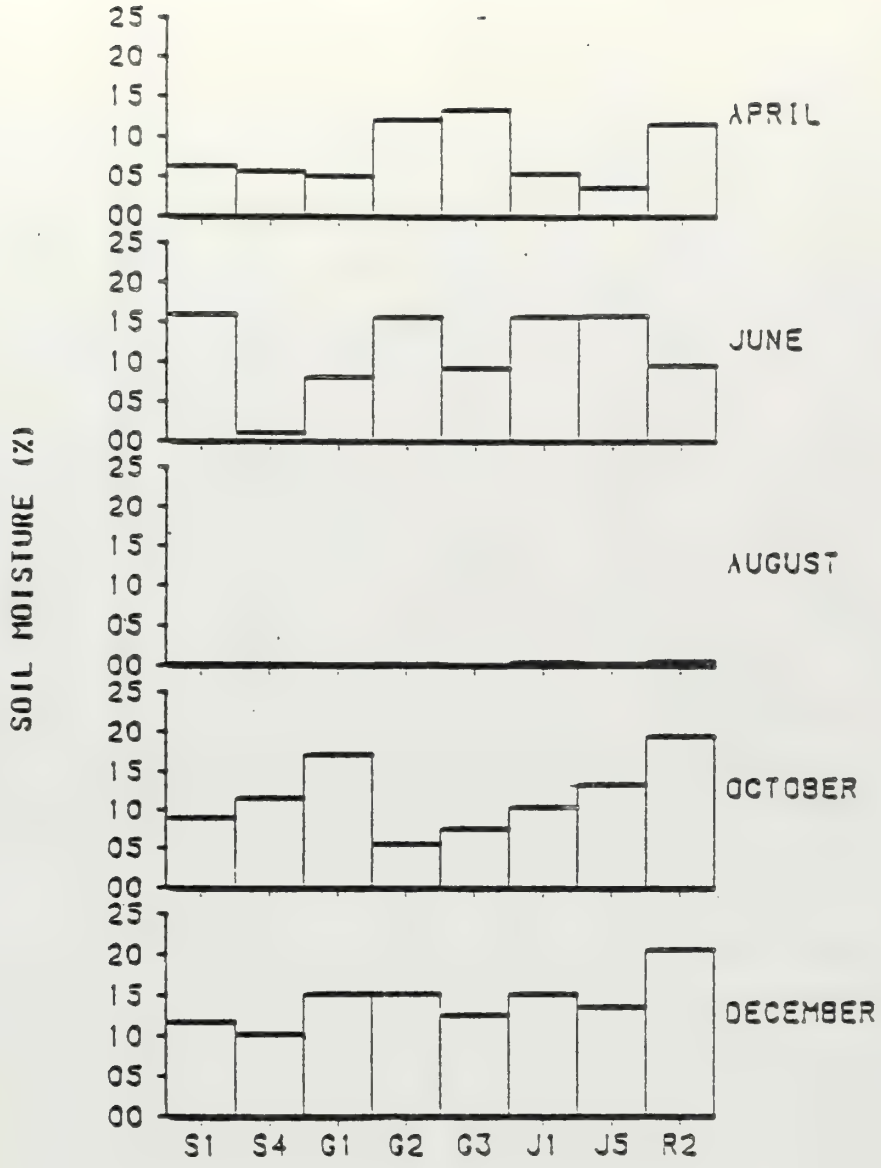

Fig. 4.4-2. Percent of soil moisture along eight transects for five months. The first letter of the transect designation indicates vegetation type. Shadscale (S), Greasewood (G), Juniper (J), Riparian (R). See Fig. 4.4-1 for transect locations.

Mojave Desert, many arthropods migrate deeper into the soil to escape desication (Wallwork 1972). Similar data are lacking for cold deserts. In the cryptobiotic state, nematodes are resistent to over heating and freezing.

For arthropods, two alternative strategies for adapting to freezing conditions have been found. The first is freezing tolerance in which the animals simply are able to endure being frozen. The second strategy is supercooling which involves lowering the termperature at which body fluids freeze.

Species richness of nematodes on each transect was somewhat variable (Fig. 4.4-3). June and August, with an average of 12 taxa, were the months of lowest richness. Species richness was near 14 during April and approximately 15 during October and December. Considerable variability is evident, however, for each month. The total nematode species count of approximately 30 is about one third larger than for the hot desert of southern Nevada (Freckman 1974). The total number of nematodes per 100 cm^2 ranged from about 900 in August to 7400 in December (Fig. 4.4-4). Comparable data for the Mojave Desert and Arctic areas range from 20,000 to 423,000 individuals (Chernov et al. 1977, Freckman and Mankau 1977). Differences in extraction procedures used in this study forced the active nematodes to migrate out of the sample, while the techniques used in the cited studies separated many inactive specimens. Further, the extraction procedure used in the above-cited studies involved wetting the sample with fresh water whereas this study used a salt water procedure. Inactive nematodes may become active within minutes as indicated previously.

Richness of arthropod taxa per transect (Fig. 4.4-5) varied from a low near 5 taxa in August to a high of 32 in April. Taxa richness was lowest in summer. Total densities (per 100 cm^2) ranged from near zero in August to a high of about 175 in April (Fig. 4.4-6). Summer densities

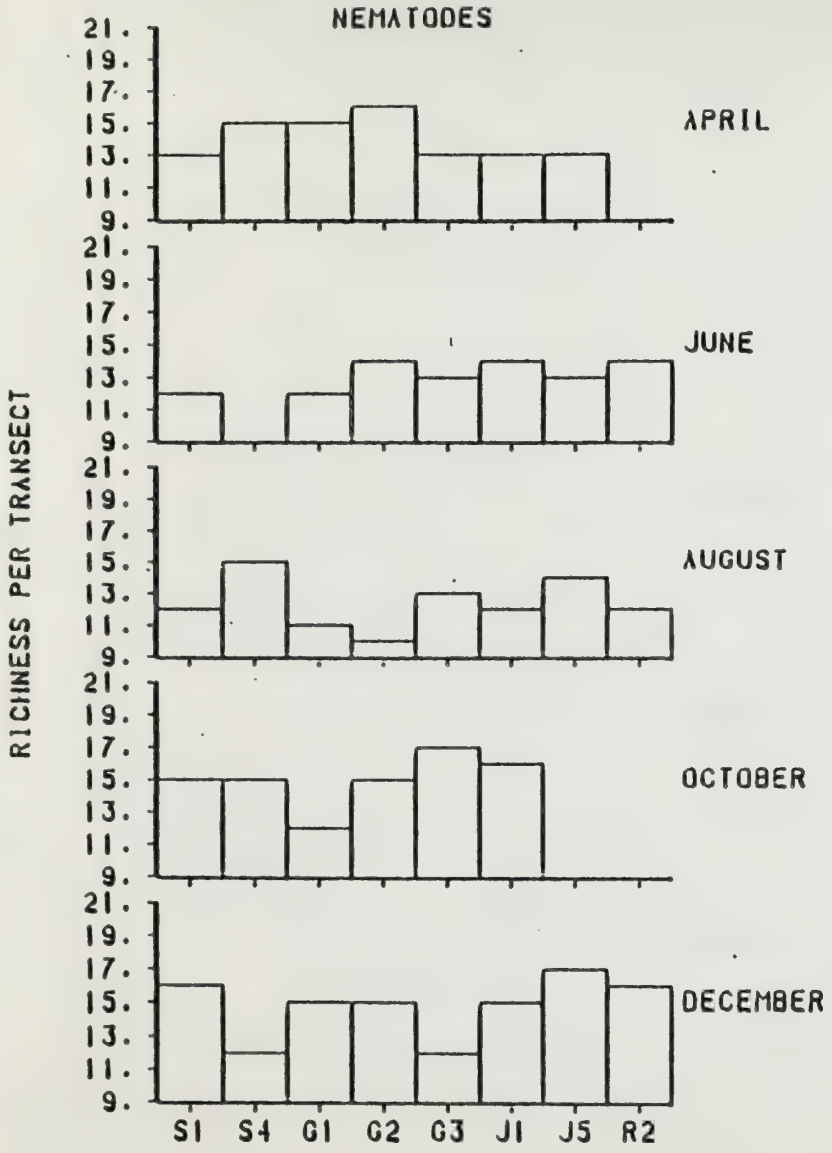

Fig. 4.4-3. Species richness of nematodes.

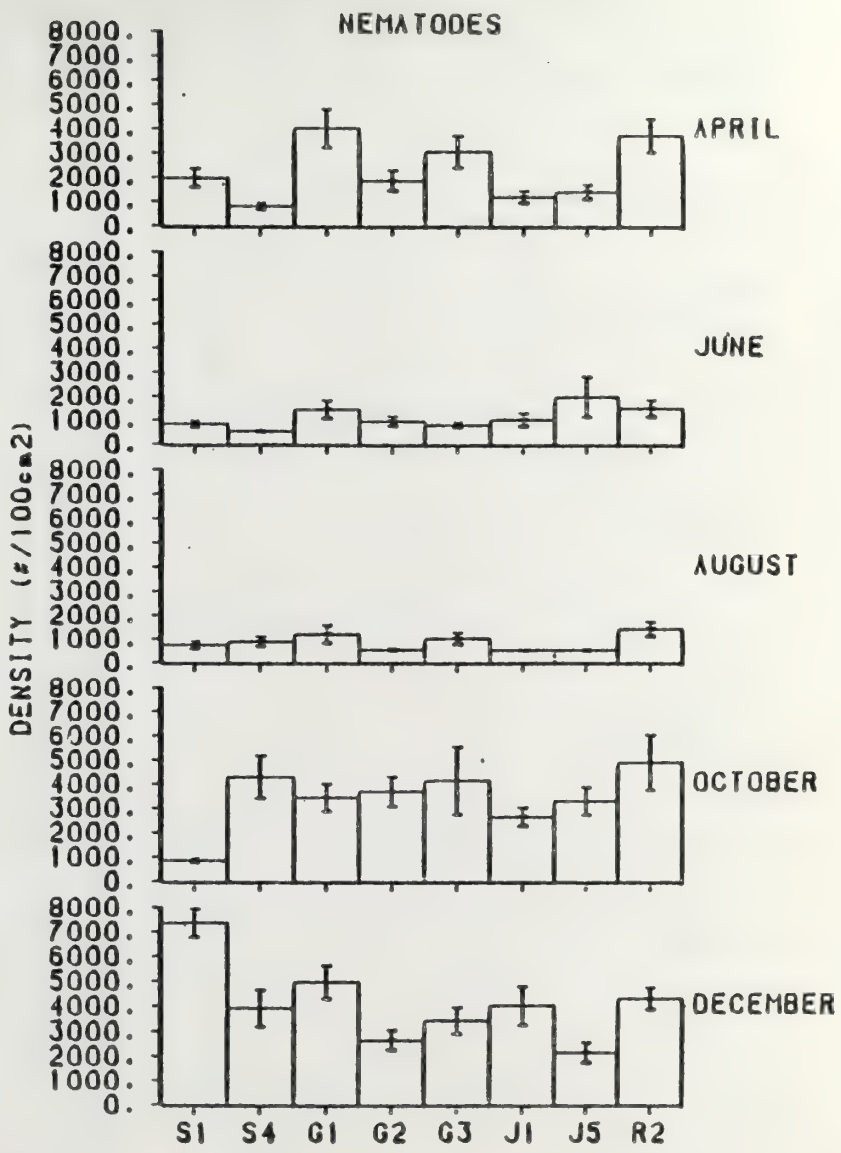

Fig. 4.4-4. Nematode density (individuals/100 cm^2) per sample.

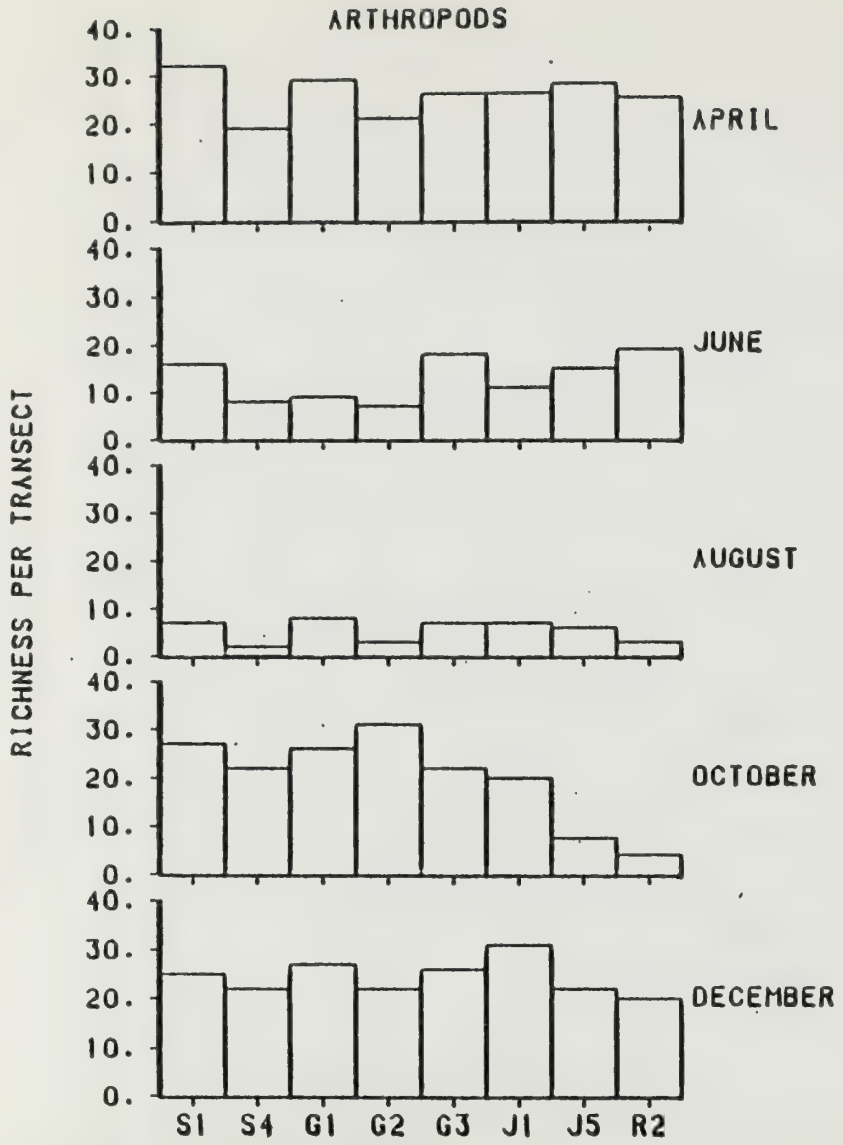

Fig. 4.4-5. Taxa richness of arthropods.

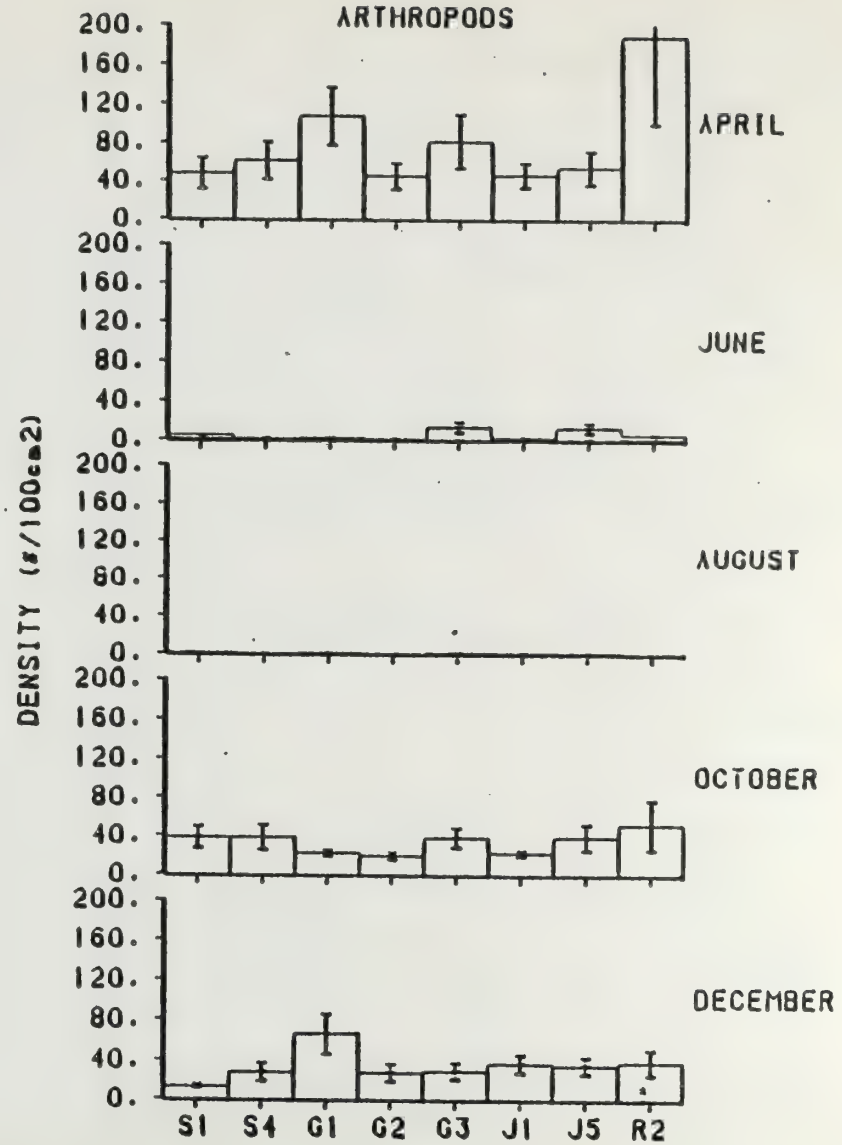

Fig. 4.4-6. Arthropod density (individuals/100 cm^2) per sample.

were very low. However, densities at other times were comparable to or somewhat higher than those for various hot deserts (Franco et al. 1979, Crawford 1981). The low values in numbers of species and total densities during the summer may have two explanations. First, most soil organisms may have been inactive. Second, the soil biota may have migrated deeper in the soil. These data indicate that during the summer very few individuals survive near the soil surface. At other seasons, many species and individuals occupied the surface stratum.

4.4.3.4 Conclusion Cold deserts, such as that of the Uinta Basin, represent physically severe habitats for the soil fauna and microflora. Extremes of temperature from a near lethal heat to below freezing, severe drought during the warmer months and reasonable moisture levels during the colder months combine to make this ecosystem one of exceptional rigor. Organisms living under such stress are often sensitive to external impacts. Monitoring of these animals may therefore yield early indications of adverse effects by external agents on the system as a whole.

Essentially no data are available from the literature on the soil-litter fauna of cold deserts. The current data set is therefore unique. Considering the range of density and species richness, it is clear that an appreciable array of soil biota is present in the four habitats sampled on the Utah Oil Shale Tracts, Ua and Ub. Further, considering the assortment of trophic groups represented, it is evident that this biota is an integrated component of the ecosystem.

Summer drought and heat notably inhibit decomposition processes. These processes are accelerated during the spring and fall when moisture

and temperature conditions are amenable to decomposition. However, since the organisms obviously survive during the winter, significant activity may occur during daily surficial melting.

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4.4.4 Terrestrial Invertebrates

4.4.4.1 Introduction Although terrestrial invertebrates are not traditionally incorporated into environmental monitoring programs, this often inconspicuous fauna is an important component of the environment. Invertebrates influence all aspects of plant community dynamics: dispersal, germination and establishment of seeds, population distribution and dispersion, productivity, and reproduction. Invertebrates are also important in explaining changes in insectivorous bird, mammal and reptile populations.

Criteria for choosing potentially useful invertebrate indicators should include an assessment of the fidelity with which subject populations reflect man-caused environmental change. Host-specific, herbivorous, invertebrates, because of their close association to a single plant species, may function as useful indicators in this case. However, to realize their value as indicators it is necessary to separate natural population fluctuations from artifically-induced impacts.

An extensive data base is needed to establish the normal ranges of faunal characteristics. To establish the baseline data for a wide variety of invertebrate species would be a task of enormous magnitude. Consequently, research should be focused upon certain species whose value as indicators is related to their close association with an important plant species.

The invertebrate sampling completed during the 1981 field season was designed to investigate taxonomic and trophic structure as well as seasonal and spatial dynamics of the terrestrial invertebrate fauna of Tracts Ua and Ub. The analysis is hierarchically arranged, examining

invertebrate faunas of individual hostplant species, then focusing on successively more-refined subsets of the faunal elements of each hostplant species. The parameters examined were: abundance (individuals/m^3), biomass (mg/m^3), family level diversity (H') and richness.

4.4.4.2 Methods Terrestrial invertebrates were sampled monthly from April to October. Two sampling locations in each of four habitats yielded: (1) eight replicates of 20 plants each on sagebrush (Artemisia tridentata) (10 plants taken from August to October); (2) two replicates of 10 plants each on rubber rabbitbrush (Chrysolthamnus nauseosus); and (3) single monthly samples of 10 plants each on shadscale (Atriplex confertifolia), green rabbitbrush (C. viscidiflorus), juniper (Juniperus Osteiosperms), greasewood (Sarcobatus vermiculatus), and spiny horsebrush (Tetradymia spinosa). Sampling locations were along line transects (see General Methods).

At equal intervals along each one-kilometer transect the invertebrate fauna of an individual shrub was sampled. At the start of each transect, cloud cover, ambient temperature, wind speed and direction were recorded. Each plant sampled was measured for maximum height and width to calculate shrub volume (m^3). Samples were obtained using a sweep net with 10 to 20 strokes per shrub, emptied in separately-labelled paper bags and placed into killing cans. Samples were then refrigerated to prevent dehydration and mold growth until they could be processed at a later date.

Invertebrates were separated from debris and identified to family, genus, or species, then tallied and assigned to one of nine feeding-types.

Feeding-types were placed in vials and oven dried (35°-45°C for 48 hours.) and weighed to the nearest 0.1 mg. Vials were then capped and placed in storage for future reference and validation.

All invetebrates were placed in one of nine feeding-type categories: zoophagic/chewing (ZC), zoophagic/sucking (ZX), parasitoid (P), phytophagic/chewing (PC), phytophagic/sucking (PS), saprophagous (S), omnivorous (OM), non-feeding (N), and flower-and-nectar feeding (FN).

The following natural history characterizations of the feeding type family units are condensed from Borror, DeLong and Triplehorn (1976).

A. Zoophagic chewers are predaceous and are characterized by having biting-chewing mouthparts. The majority of these are spiders (Araneida) and mites (Acarida). The other taxa in this group include adult and larval beetles (Coleoptera) and a sphecid wasp (Hymenoptera:Sphecidae).

B. Zoophagic suckers are also predaceous but are characterized by having sucking mouthparts. When these taxa capture their prey they insert their proboscis into the body cavity and remove the fluid within. Included in this group are those adult flies (Diptera) which are also pests to man; no-see-ums (Ceratopoganidae), mosquitoes (Culicidae), black flies (Simuliidae), and horse flies (Tabanidae). Other adult flies in this group include long-legged flies (Dolichopodidae), dance flies (Empididae) and robber flies (Asilidae). This family includes many large species which are speedy fliers, attacking prey on the wings. The true bugs (Heteroptera) are also an important compnoent of the zoophagic/sucking group. These include minute pirate bugs (Anthocoridae), three genera of plant bugs (Miridae), damsel bugs (Nabidae), stink bugs (Pentatomidae), ambush bugs (Phymatidae), and assassin bugs (Reduviidae).

C. Parasitoids are represented on the tracts by members of the orders Hymenoptera and Diptera. Although the majority of the parasitoids captured were in the adult life-stage and as such are not parasitic, they were recently parasitoids as larvae, and their larval progeny will be parasitoids. The adults were treated as parasitoids because of their temporal proximity to the parasitoid feeding-type and the fact that our sampling program inadequately sampled larvae.

D. Phytophagic chewers have biting-chewing mouthparts and feed on plant tissue. Orders represented in this group are Coleoptera (beetles), Lepidoptera (moths) and Orthoptera (grasshoppers and crickets). Coleopterans were leaf beetles (Dascillidae) and scarab beetles (Scarabidae). Lepidopterans were represented largely by unidentified larval stages (catepillars). The identified larval lepidopterans were case-bearers (Coleophoridae) and geometer moths (Geometridae). In the larval stage they are voracious plant consumers but in the adult stage most will be nectar feeders. Orthopterans captured were short-horned grasshoppers (Acrididae), long-horned grasshoppers (Tettigoniidae), and crickets (Gryllidae). Orthopterans were captured in smaller numbers but because of their larger size consume more plant tissue and in effect become just as important as the other two orders in this feeding-type.

E. Phytophagic suckers are characterized by having piercing-sucking mouthparts used to tap plant fluids. The orders represented in this group are Homoptera (mainly scale insects, aphids, leafhoppers and psllids), Thysanoptera (thrips), and Hemiptera (true bugs, primarily Miridae or plant bugs).

F. Saprophores are characterized by having biting-chewing mouthparts and feeding on mold, fungi, and dead organic matter. Collembola (springtails), Psocoptera (psocids), and Coleoptera (beetles) were the representative orders collected.

G. Omnivores captured on the site were ants (Formicidae) of the order Hymenoptera. They are general foragers which feed on seeds, plant tissue, fungi, other insects, dead organic matter, and often tend aphids for their honeydew. Some of the larger catches of ants were made on shrubs where large numbers of aphids were also taken.

H. Non-feeders are represented here by the adult mayflies in the order Ephemeroptera, and other pupae of several other orders. Pupae of parasitoid Hymenoptera and Diptera as well as phytophagic/chewing Lepidoptera and Coleoptera are the most prevalent members of this feeding-type.

I. Flower-and-Nectar-feeders consume nectar from flowering shrubs and plants. Some have sucking mouthparts and others have sponging or lapping mouthparts. Lepidopterans represented here are the micro-lepidopteran (minute moths). The Dipterans comprise thirty-five families. The significant taxa, in order of abundance, are midges (Chironomidae), dark-winged fungus gnats (Sciaridae), leaf-miner flies (Agromyzidae and Anthomyiidae), gall midges (Cecidomyiidae), bee flies (Ephydridae), tachinid flies (Tachinidae), dance flies (Empididae), aphid flies (Chamaemyiidae) and fruit flies (Tephritidae). Common names of these flies usually refer to their habits in the larval stage, which are usually much different than habits during the adult stage.

4.4.4.3 Results and Discussion Total abundance of terrestrial invertebrates collected by sweep net from April to October on all seven hostplants was 4906 individuals. Total biomass was 7.5 gm (Table 4.4-3). Adults accounted for 67% of all invertebrates collected. The low number of larvae and pupae collected may have been due to ineffi- ciency in sampling these life-stages by sweep net. Even with this qualification, the ratio of adults to immatures reliably describe seasonal trends in life-stage structure. The percent of immatures peaked in May, decreased through September, and then peaked again in October. Percent of adults had two peaks: one in early summer (June) and another in early fall (September). The fall peak in immatures indicates a predominance of larvae and nymphs reaching the pupal and adult stages in preparation for overwintering. The Aranida, in terms of percent of total occurrances, peaked in August and did not increase in late season.

For the entire invertebrate fauna significant differences exist among hostplant species and months in individual abundance, diversity and biomass (Table 4.4-4). The interaction between months and hostplants was significant for the invertebrate fauna parameters of abundance and diversity ($p<0.05$). This indicates that the fauna of a hostplant species responds to the phenology of that hostplant differently than other fauna respond to their hostplant phenology. For example, juniper and shadscale supported fauna that peaked in abundance by June and remained at low levels throughout the remainder of the year. Rubber rabbitbrush and green rabbitbrush supported fauna that reached a peak in July, decreased substantially in August, then increased dramatically in October (Fig. 4.4-7).

Table 4.4-3. Trophic composition of terrestrial insect fauna in terms of individual occurrences and observed biomass for 1981.

A.

Feeding Type	Total # of Occurrences	% of Total	Total Biomass mg	% of Total
Zoophagic chewing	562	11.5	985.9	13.0
Zoophagic sucking	267	5.4	290.4	3.8
Parasitoid	436	8.9	187.2	2.5
Phytophagic chewing	614	12.5	3285.9	43.3
Phytophagic sucking	2194	44.7	1507.9	19.9
Saprophagic	116	2.4	14.3	0.2
Omnivorous	143	2.9	940.3	12.4
Non-feeding	55	1.1	38.0	0.5
Nectar & flower feeding	557	11.4	340.8	4.5
TOTAL	4906		7590.7	

B.

Life Stage	# of occurrences	% of total
Larvae	297	6.7
Nymphs	809	18.2
Pupae	51	1.2
Adults	2933	66.0
Alate aphids	56	1.3
Apterous aphids	293	6.6
TOTAL	4439	
All Adults		67.3
All Immatures		32.7

Table 4.4-4. Significance of Analysis of Variance for population parameters of terrestrial invertebrates on all hostplants temporally and spatially, on specific hostplants, temporally and spatially, and feeding types on sagebrush, temporally and spatially.

	Abundance	Diversity	Biomass
A. All Host Species			
Host (H)	**	**	**
Months (M)	**	**	**
Vegetation Type (T)	*	**	--
HM	*	**	--
HT	**	**	--
MT	*	**	--
B. Sagebrush			
Month	**	**	**
Vegetation Type	**	**	**
MT	--	**	*
Rubber Rabbitbrush			
Month	**	**	**
Vegetation Type	--	**	--
MT	--	*	--
Green Rabbitbrush			
Month	--	**	**
Shadscale			
Month	--	--	--
Greasewood, Juniper, Horsebrush	**	**	--
C. Feeding Types on Sagebrush by Percentage			
Month	**		
Vegetation Type	**		
Feeding Type (F)	**		**
FM	**		**
FT	--		--

** $p < .01$
* $p < .05$
-- not significant

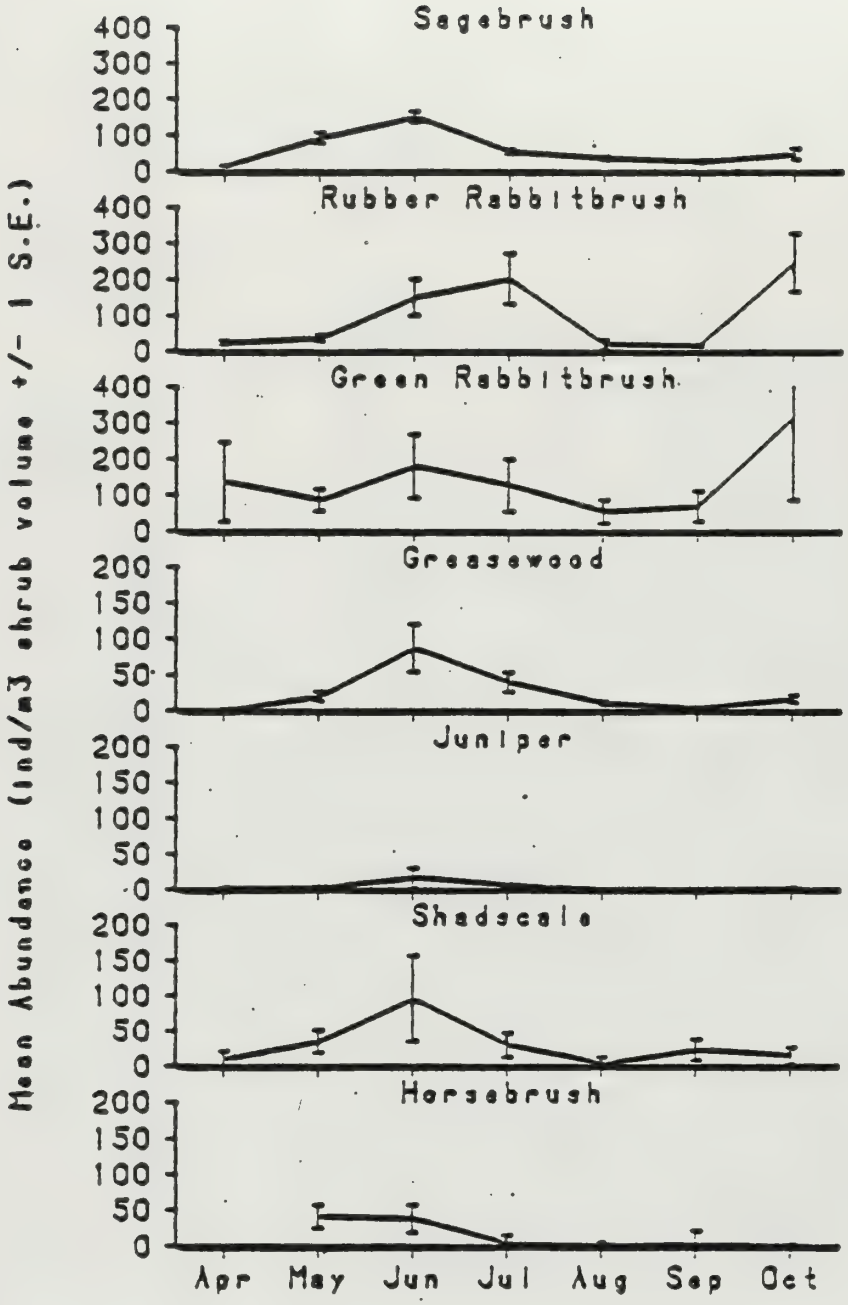

Fig. 4.4-7. Mean abundance (individuals/m^3 shrub volume) of all invertebrates on seven plant species through 1981.

The pattern of high and low values for the invertebrate faunal characteristics and rankings of feeding-types for the entire site provided a base upon which the patterns found in the more specific analysis sections can be compared. Total abundance, diversity, and taxonomic richness were greatest in June and August. Low values for these faunal characteristics were in spring (April) and later summer (August through September). There was a slight increase in all characteristics except diversity in October.

Non-parametric multiple comparisons of feeding-types ranked by abundance was difference from a similar ranking using biomass. In terms of abundance the phytophagic/sucking feeding-type generally ranked highest with the phytophagic chewers in the next group. Ranking by biomass gave the reverse order of these two types in most cases. Third highest in both ranking methods was the zoophagic chewers. Fourth in the abundance rank were the flower-and-nectar feeders, but ranked by biomass the omnivores (ants) were fourth.

Sagebrush was sampled in all four vegetation-types because of its wide and dominant distribution on the tracts. This sampling regime permitted analysis of the effect of vegetation type on the invertebrate fauna of the same hostplant species.

Peak values for some of the faunal characteristics on sagebrush by vegetation type occurred during different months than when the entire site was analyzed (Fig. 4.4-8). Sagebrush fauna in Riparian had peak diversity earlier (April) than fauna on all other vegetation-types. This may be the result of more moisture available to the plants at that time of year than in the other vegetation-types. Peak biomass occurred earlier

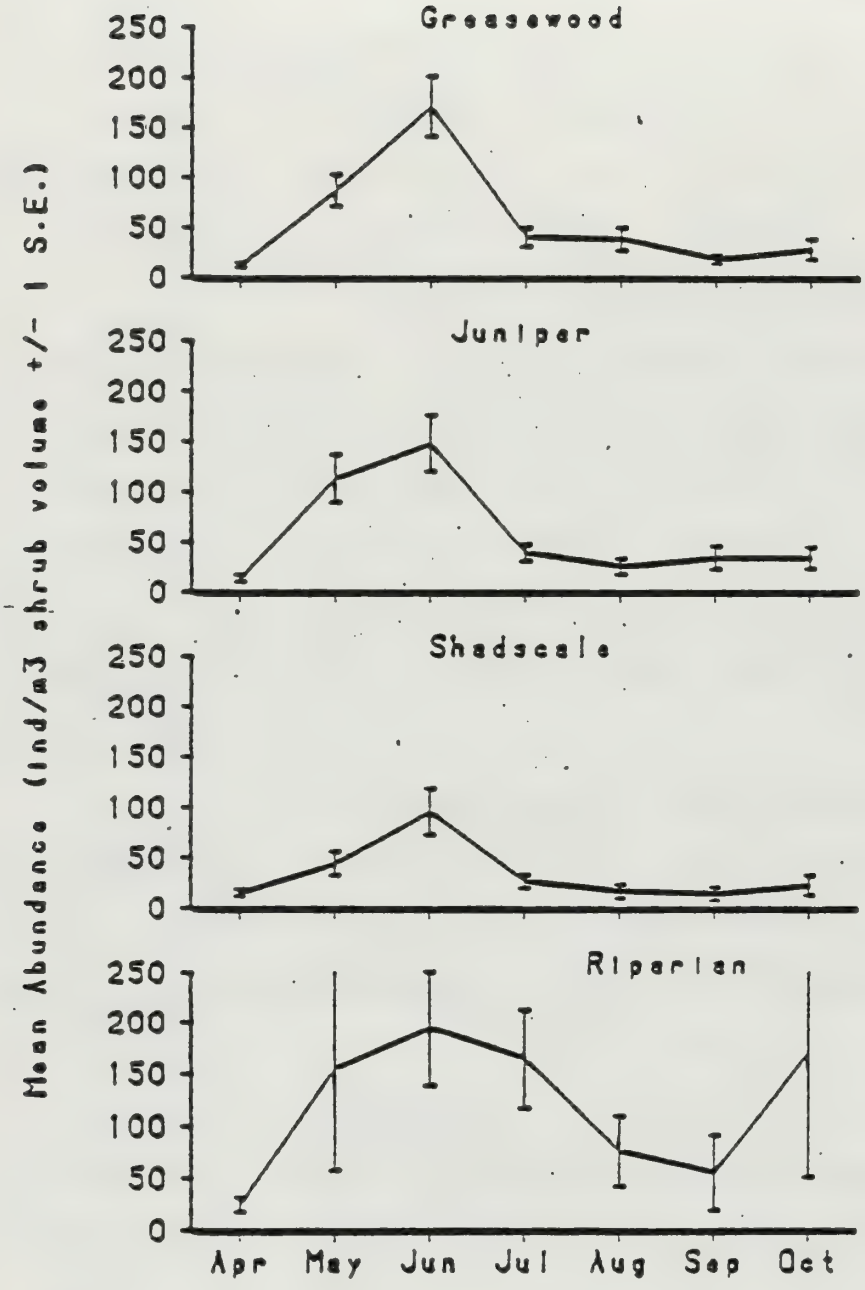

Fig. 4.4-8. Mean abundance of all invertebrates on sagebrush from four vegetation-types through 1981.

on juniper and shadscale sites (June and July, respectively) indicating a more rapid completion of faunal development on these drier vegetation-types. Low values for the faunal characteristics occurred in the same months as described under the entire site summary.

Sagebrush in Riparian (April and September) supported slightly more invertebrates during the year than did sagebrush in the other vegetation-types. Abundance and biomass values were greatest in Riparian. The next greatest values were for Greasewood, the least were for Shadscale. Taxonomic richness values showed the same pattern as did those for biomass, with Riparian having the most taxonomic groups and Shadscale the fewest.

Feeding-type rank on sagebrush in different vegetation types did not differ greatly from the patterns for all habitats combined. Whether ranked by abundance or biomass, phytophagic suckers were ranked first and phytophagic chewers were ranked second in most vegetation type. However, in Greasewood this order was reversed. Zoophagic chewers were ranked third by abundance or biomass for all the vegetation-types.

On all levels of analysis marked seasonality in the invertebrate fauna was apparent. These dynamics are best explained by plant phenology, which is ultimately influenced by temperature, precipitation and photoperiod. The dormant stage of an invertebrate insect may be any one of the life-stages but is usually an egg or pupae which will resume its development upon the accumulation of a certain number of degree/days (days above a certain initiating temperature).

Many overwintering stages of invertebrates in the phytophagic feeding-type are situated, by virtue of parental placement, within or

near rapidly-developing plant tissues such as leaf buds or seeds. The invertebrates make use of the nutritious and succulent developing vegetation upon becoming active. Dormant zoophagic and parasitoid feeding-types are also oviposited near potential prey. Parasitoids may have diapaused within the diapausing prey egg or pupae.

The phytophagic suckers are very closely tied to the moisture and nutrient dynamics of their hostplants. Plant development is rapid during spring and early summer when moisture is available but the sustained heat and low precipitation in or through July and August reduces this growth. Plant-resources are then diverted to the development of reproductive structures and seed. Phytophagic suckers, if univoltive (one generation per year), as in Miridae will develop from an egg, go through five nymphal stages, achieve adulthood, mate, and perhaps disperse, lay eggs and die before the end of June. The egg stage must be able to withstand the dry conditions of summer as well as winter cold. This scenario is typical in the driest Shadscale vegetation-type. Shadscale and horsebrush were essentially devoid of invertebrate life by July in 1981. The sagebrush plants within this vegetation-type showed the lowest amount of invertebrate production when compared to sagebrush in other vegetation-types.

In other phytophagic/sucking groups, where the life cycle is bi- or multi-voltive, different generations will take advantage of the reproductive structures of the host shrub. This situation was observed on the moist Riparian and Greasewood vegetation-types. In terms of abundance and biomass there was a 21-fold and 30-fold increase, respectively, in the phytophagic suckers on rubber rabbitbrush between September and October sampling periods.

Invertebrate faunas of vegetation-types were analyzed on two levels in this study: (1) all hostplants within each vegetation type combined; and (2) sagebrush within vegetation types. The results indicate that there is a strong correlation between plant production, which is strongly influenced by available moisture, and peak invertebrate characteristics. The Riparian had the greatest invertebrate abundance, biomass, and taxonomic richness of the four vegetation types when considered in terms of all hostplants or sagebrush alone.

The remaining vegetation types considered in order of decreasing magnitude for the same faunal characteristics were Greasewood, Juniper and Shadscale. The Riparian and Greasewood had the most soil moisture by virtue of high water table and concentrated rainfall runoff. High availability of moisture allowed for succulent vegetation and consequently abundant invertebrate fauna. Diversity did not show this pattern when all hostplants were considered. Although the peak diversity values of the top three vegetation types were not widely separated, Riparian had the highest diversity.

The analysis at the hostplant level shows that the seven plant species supported quite different invertebrate faunas and that the faunas responded to the seasonal progression of environmental parameters in differing manners. Sagebrush had much higher diversity than any of the other hostplants. Sagebrush and rubber rabbitbrush had similar mean taxonomic richness per sample and both were considerably more rich in invertebrate families than other plant species studied. However, during the course of the entire year 30% more families were found on sagebrush than rubber rabbitbrush.

Table 4.4-5 compares the invertebrate fauna on Ua and Ub with another cold desert fauna in Curlew Valley, Utah (MacMahon et al. 1975) and the fauna of an old field in Michigan (Evans and Murdock 1968). All three studies involved extensive collecting utilizing many sampling techniques. What is interesting about this, albeit basic, comparison is the similarity between the different sites. Even though Curlew Valley has less than half and the old field has three quarters of the number of species collected at Ua and Ub, the taxonomic and trophic structure is strikingly similar. Both the advanced and primitive insect orders include the same percentage of species in Ua/Ub and in the old field. The trophic structure in terms of herbivore-to-carnivore species is quite similar; the ratio is 9 to 1 for adults and practically 1 to 1 for immatures. These findings are probably indicative of the composition of most terrestrial insect communities (Evans and Murdock 1968).

4.4.4.3 Literature Cited

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MacMahon, J. A., R. S. Shinn, R. A. Anderson, M. Merritt and W. Osborn. 1975. Curlew Valley Validation Site Report. US/IBP Desert Biome Res. Memo. 75-1. Utah State Univ., Logan. 68 pp.

Table 4.4-5. Comparison of two cold desert and old field community compositions (terrestrial fauna).

Species Data	WRSP	Curlew Valley*	Old Field**
# of Orders	14	14	15
# of Families	213	152	179
# of Species	2,187	762	1,584
% of Total Species Contributed by: Hymenoptera, Diptera, Coleoptera and Lepidoptera	86%	80%	86%
Hemiptera, Homoptera, Orthoptera and Thysanoptera	12%	18%	12%
Trophic Structure (data from Table 5.2-22)			
Adults			
% of Herbivorous species	90%	86%	86%
% of Carnivorous species	10%	14%	12%
Immatures			
% of Herbivorous species	47%	49%	41%
% of Carnovorous species	53%	51%	52%

*US/IBP Desert Biome Validation Studies Vol. 2 1975
**Evans and Murdock 1968

4.4.5 Amphibians and Reptiles

4.4.5.1 Introduction Amphibians and reptiles have frequently been overlooked in baseline programs in favor of the conspicuous and economically-important birds and mammals. However, some amphibians and reptiles may be equivalent to birds and mammals as indicators of environmental quality. This section describes changes in amphibian and reptile populations over years (1975 through 1981) and seasons (June and August) and describe differences in community structure between habitats (Greasewood, Juniper, Shadscale and Riparian).

4.4.5.2 Methods Estimates of amphibian and reptile populations were made along line transects (see General Methods) walked between 0900 and 1200 (MDT) on five consecutive days. Abundances are reported as number of individuals encountered per km of flushing transect. Few individuals were seen at a distance greater than 3 m from the transect. A belt transect of 6 m wide and 1 km long would census about 0.6 ha. Thus, a minimum estimate of species density was calculated as:

Density (ind/ha) = Abundance (ind/km)/0.6 (ha/km)

Because most amphibians and snakes were seldom seen along line transects, much of our conclusions concerning these species are based on casual observations, and, for amphibians, records of auditory observations made throughout the study tracts.

4.4.5.3 Results

A. Amphibians Based on casual observations, amphibians were most abundant in 1975 and 1976 and have since become less common. Most amphibians were encountered in the Riparian habitat. The distribution of two species, the leopard frog (Rana pipiens) and the chorus frog

(Pseudacris triseriata) were limited to small backwaters and banks of the White River. Neither of these species has been observed since 1977. The Great Basin spadefoot (Scaphiopus intermontanus) and Woodhouse's toad (Bufo woodhousei) were abundant along the White River during 1975 and 1976. Since 1977 they have been found primarily at ephemeral and perennial stockponds in Asphalt Wash and near Bonanza, Utah with occasional encounters along the White River.

A new species for the Uinta Basin, the red-spotted toad (Bufo punctatus), was found in June, 1980 at a small pond in Asphalt Wash (T10S, R24E, S6, NE 1/4). The distribution of the red-spotted toad was previously thought to be south and east of the Colorado River in Utah (Stebbins 1966). No specimens have been observed in the study area since 1980.

Seasonal activity patterns of amphibians varied with spring weather patterns. During the cold wet spring of 1975, activity peaked in June and lasted through August. In the dry spring of 1977, activity peaked in early May and lasted through June.

B. Reptiles Six species of lizard and five species of snake were recorded on the study tracts. The eastern fence lizard (Sceloporus undulatus) and the tree lizard (Urosaurus ornatus) were encountered more frequently in wooded habitats than in shrub habitats ($p<0.01$), the habitats with the highest percentage of bare ground. The sagebrush lizard (Sceloporus graciousus), the most abundant lizard on the tracts, was in nearly-equal abundance throughout the upland communities, but was observed less frequently in the Riparian community ($p<0.05$) where it was still the most abundant in all four habitats. The least-frequently

encountered lizard, the short-horned lizard (Phrynosoma douglassi) or horned toad, was most abundant in Shadscale.

The most-frequently encountered snake was the gopher snake (Pituophis melanoleucus), although the line transect observations do not support this conclusion. The racer (Coluber constrictor) was the most abundant snake in the Riparian community, and the midget-faded rattlesnake (Crotalus viridis concolor), a subspecies of the western rattlesnake, was most abundant in Greasewood.

4.4.5.4 Discussion

A. Changes Over Years Lizards, as a group varied in density over the seven years from 4.8 to 9.4 individuals per ha. Total lizard abundance reached a seven year peak during the 1977 drought and a seven year low in 1979 (Table 4.4-6). They increased again in 1980 and remained abundant in 1981.

Changes in lizard abundance over seven years appeared to be related to climatic conditions, especially the mildness of the winters and the warmth of the summers. For example, high lizard abundance in 1977 followed the mildest winter of the seven-year study and occurred during the summer of highest mean temperature and solar radiation. This relationship is confounded, however, by the relocation of a line transect in Shadscale between 1976 and 1977 (WS-3 to WS-4) which may be partially responsible for the increased number of lizards observed. The low lizard abundance of 1979 followed the most severe winter of the study period and occurred during the summer of lowest mean temperature and solar radiation.

Table 4.4-6. Mean lizard abundance, species richness and species diversity over seven years. Comparisons below each column show significant differences (a=0.05) between years. Differences among years for species richness were not significant.

	Abundance (Ind/km)	Species Richness (No. spp)	Species Diversity (H')
1975 (1)	4.0±0.4	4.8±0.7	1.09±0.14
1976 (2)	4.2±0.6	4.1±0.7	0.89±0.18
1977 (3)	5.6±0.8	5.1±0.7	1.20±0.14
1978 (4)	4.9±0.8	4.6±0.5	1.12±0.12
1979 (5)	2.9±0.3	4.8±0.6	1.18±0.15
1980 (6)	5.4±1.1	4.6±0.4	1.26±0.10
1981 (7)	5.0±0.8	4.5±0.4	1.12±0.99
	3>1,2,5 6>1.5 4,7>5		3,5,6>2

Species richness of snakes and lizards seen on transect did not change markedly through seven years. Species diversity fluctuated moderately but showed no discernible trends. None of the individual species (lizards or snakes) had significant changes in abundance between years (one-way Analysis of Variance, $p<0.05$).

The highest concentration of reptiles occurred in the Juniper (three-way Analysis of Variance, $p<0.001$, Table 4.4-7), the habitat with the sparsest vegetation cover and least soil. Shadscale supported the second-highest concentration of reptiles and, also, had a low percentage

of vegetation cover. The amount of bare ground was significantly correlated with reptile abundance ($r=0.88$, $df=5$, $p<0.01$). Riparian, which supported the lowest abundance of reptiles, had the highest species richness and the highest species diversity.

B. Changes Over Seasons Reptile activity periods are dictated by ambient weather conditions which restrict their activity to warmer months of the year. During the winter occasional lizards were found on south-facing rock outcrops. These encounters occurred on clear days when the temperature exceeded 4°C. In the spring, as the weather warmed, reptiles were first observed more-frequently on rock outcrops and then, as the soil warmed and dried, on the ground. Reptile sightings were more numerous in June than in any other month (three-way Analysis of Variance, $p<0.001$). Juvenile reptiles were first encountered in August. By October, sightings of reptiles were again infrequent.

Table 4.4-7. Mean lizard abundance, species richness, and species diversity in four habitats. Comparisons below each column show significant difference ($a=0.05$) between habitats.

	Abundance (Ind/km)	Species Richness (No. spp)	Species Diversity (H')
Greasewood (G)	3.4±0.3	3.8±0.3	0.88±0.07
Shadscale (S)	5.1±0.7	4.3±0.4	1.02±0.12
Juniper (J)	7.1±0.7	5.1±0.2	1.25±0.04
Riparian (R)	2.6±0.5	5.4±0.6	1.34±0.10
	J>G,S,R S>G,R	R,J,S>G	R,J>G,S

Amphibians were minor components of the total vertebrate fauna on the study tracts. This was not surprising since amphibians require permanent or ephemeral water for reproductive purposes. Much of the study tract is too arid or too distant from permanent water to support populations of amphibians. Even along the White River, variable flow rates and high sediment loads result in suboptimal habitat for amphibians. Permanent populations of amphibians exist only at a few permanent ponds (i.e., Asphalt Wash and near Bonanza) and along certain sections of the White River.

Snakes differ from both amphibians and lizards in being predators of small vertebrates, primarily rodents. This trophic position suggests that snake population densities may change significantly due to changes in rodent populations. This situation complicates the elucidation of snake population changes. The value of snakes in monitoring environmental change is diminished by their trophic position, low population densities and their secretive habitats, a scenario which is repeated in both avian and mammalian carnivores.

The lizards provide the only quantifiable input for determining change in cold-blooded birds and mammals are numerous. Lizard activity is limited to warm seasons. Climatic factors which result in declines in bird and mammal activity result in increases in lizards and vice versa. The sparser the vegetation, the more lizards, the opposite of birds and mammals.

The value of these reptiles to monitoring impacts is due to their consistency, their high density in sparse vegetation, and their response to temperature regimes. The lizards are the most consistent fauna in

terms of species composition both across habitats and between years. A loss of one species must be considered a major change in environmental quality. An increase in lizard abundance in greasewood or riparian woodland or a decline in juniper or shadscale must also be considered indicative of a significant environmental change. Since the lizards are permanent residents, they are subject to both the mildness and harshness of the climate in a manner completely opposite of most birds and mammals.

4.4.5.5. Literature Cited

Stebbins, R. C. 1966. A Field Guide to Western Reptiles and Amphibians. Houghton-Mifflin Co., Boston, Mass.

4.4.6 Birds

4.4.6.1 Introduction This section documents the variability in bird community-structure in four vegetation types on the Tracts Ua and Ub over a seven year period. Variability was examined in three ways: (1) annual (between-year); (2) seasonal (within-year); and (3) according to habitat differences. In addition, environmental factors that influence changes in community structure are identified. The environmental factors which were chosen in the analysis (i.e., annual precipitation [water-year], spring precipitation [April-June], annual-plant biomass, and sagebrush leader-growth) are meaningful indices of environmental quality.

To facilitate analysis, the avian community was examined at three levels: (1) total community; (2) trophic groups and guilds; and (3) individual species within guilds. Results will aid in following the pathways of potential impacts within the bird community during tract development and mining operations.

4.4.6.2 Methods Bird communities in four habitats were censused using line transects following the procedure of Burnham et al. (1980). Transect locations are shown in Figure 4.4-1. Transects were walked shortly after sunrise on five consecutive mornings. Population densities were estimated using the computer program "TRANSECT" developed by the Utah Cooperative Wildlife Research Unit (Burnham et al. 1980). This method fits a curve generated by a Fourier Series to the distribution of perpendicular distances for all sightings of a species in each habitat and calculates a density based on this detectability curve. 30 to 40 sightings were usually required to construct a reliable distribution.

When fewer sightings were available, which was often the case in these sparsely populated habitats, species with similar detectabilities (e.g., all sparrows, all small foliage-gleaners) were combined for analysis. Species densities were then estimated by partitioning the "detectability-group" density among species based on proportional representation.

Consuming biomass was calculated according to Salt, 1957. Species biomass measurements are from Dunning (unpublished data). The equation adjusts the biomass for metabolic rate (which varies with body size) and thus consuming biomass more accurately represents the energetic demands made on the ecosystem by a species than does density (Karr 1968, Emlen 1977).

Common and scientific names of birds follow the A.O.U. Checklist 1973, 1976.

All birds which occurred on the study tract were assigned to a feeding guild based on three criteria: (1) substrate from which most food was taken (i.e., air, bark, foliage, and ground); (2) predominant foraging technique (i.e., gleaning, hawking, probing, and cruising); and (3) primary food type (i.e., insects, seeds, a near-equal proportion of insects and seeds, nectar and vertebrates). Terrestrial birds (in this study, hawks, owls and aquatic birds will be treated separately) were divided into 10 guilds based on observations of foraging techniques and/or data from the literature. These are: air-cruising insectivores (ACI), air-hawking insectivores (AHI), bark-gleaning insectivores (BGI), ground-gleaning insectivores (GGI), ground-gleaning granivores (GGG), ground-gleaning omnivores (GGO), nectarivores (N), and raptors (R).

To quantify relative importance of guild members during the breeding season (June), species dominance was determined by calculating the percentage of guild density contributed by each species for each year and then ranking the species percentages over the seven-year period following the procedure of Zar (1974, p. 111). Species were then arranged in order of decreasing rank. Significant differences in dominance rank were determined with Kruskal-Wallis and nonparametric multiple-comparison tests (Zar 1974) using sum ranks.

To obtain estimates of the invertebrate food resources available to birds foliage invertebrate data is combined with shrub volume data. Biomass of invertebrates per volume of shrub was multiplied by the average volume of shrub per unit surface area for the two or three most dominant shrub species in each habitat. This yielded estimates of biomass of foliage invertebrate per unit area.

4.4.6.3 Results A total of 146 bird species have been seen on the study site over seven years. Of these, 137 species have been divided into three categories: (1) terrestrial; (2) aquatic; and (3) raptorial (Table 4.4.8).

Terrestrial species include all those for which density estimates from transect observations were possible. Many of these species (46%) were summer residents. Riparian habitat supported the greatest number of species (89%) whereas shadscale supported the fewest species (34%). The analysis of community changes over years and seasons and between habitats which follows is based on terrestrial species. Aquatic species (those dependent on open water in the White River) and raptors (hawks and owls) will be treated separately.

Table 4.4-8. Number of bird species classified by residency status and habitat occurrence. Figures for the entire site may be less than those in each habitat because many species were seen in more than one habitat and because some species had different status in different habitats (e.g., transients in Riparian but permanent residents in Juniper).

	Number of species by habitat				
	Greasewood	Juniper	Shadscale	Riparian	Entire Site
TERRESTRIAL SPECIES					
Summer Residents	27	31	18	44	48
Transients*	13	12	5	20	16
Winter Visitors	5	2	1	4	5
Permanent Residents	6	5	5	11	16
Irregular Visitors	8	10	6	14	19
TOTAL	59	60	35	93	104
AQUATIC SPECIES					16
RAPTORS					18
NOT SEEN ON CENSUSES					9
TOTAL					146

*Transients were only present during spring or fall and include both latitudinal and elevational migrants.

4.4.6.3.1 Community Level Patterns Several patterns are evident from the changes in consuming-biomass of the terrestrial bird community over seven years (Fig. 4.4-9). First, Riparian supported the greatest consuming-biomass. Second, consuming-biomass in most habitats declined after 1975. Third, seasonal peaks occurred in every month at least once although they occurred most often in June. Seasonal peaks in October or February were due to large flocks of migrating or wintering birds that were sporadically encountered on transects.

A three-way Analysis of Variance showed that bird consuming-biomass was significantly different among years ($F_{4,68}=3.91$, $p<0.01$), habitats ($F_{3,68}=3.79$, $p<0.001$), and months ($F_{4,68}=5.20$, $p<0.001$). These differences were also found for total density, species richness, and species diversity. A significant interaction between months and habitats was found for each variable except species diversity, indicating that the season pattern was different in different habitats.

A. Changes Over Years To analyze changes over years we looked at consuming-biomass of breeding birds (June) averaged over the four vegetation types (Fig. 4.4-10). Changes were significant ($F_{6,18}=4.5$, $p<0.01$). Populations declined from 1975 through 1979 and then increased. Confidence intervals showed that most differences between years were significant.

We expected that at least some of the variation in populations could be explained by changes in food resources or precipitation on the site. Two measures of plant production were used as indices of food resources: biomass of annual plants and sagebrush leader-growth. These plant measures may relate to food supply through a number of pathways (e.g., seed production).

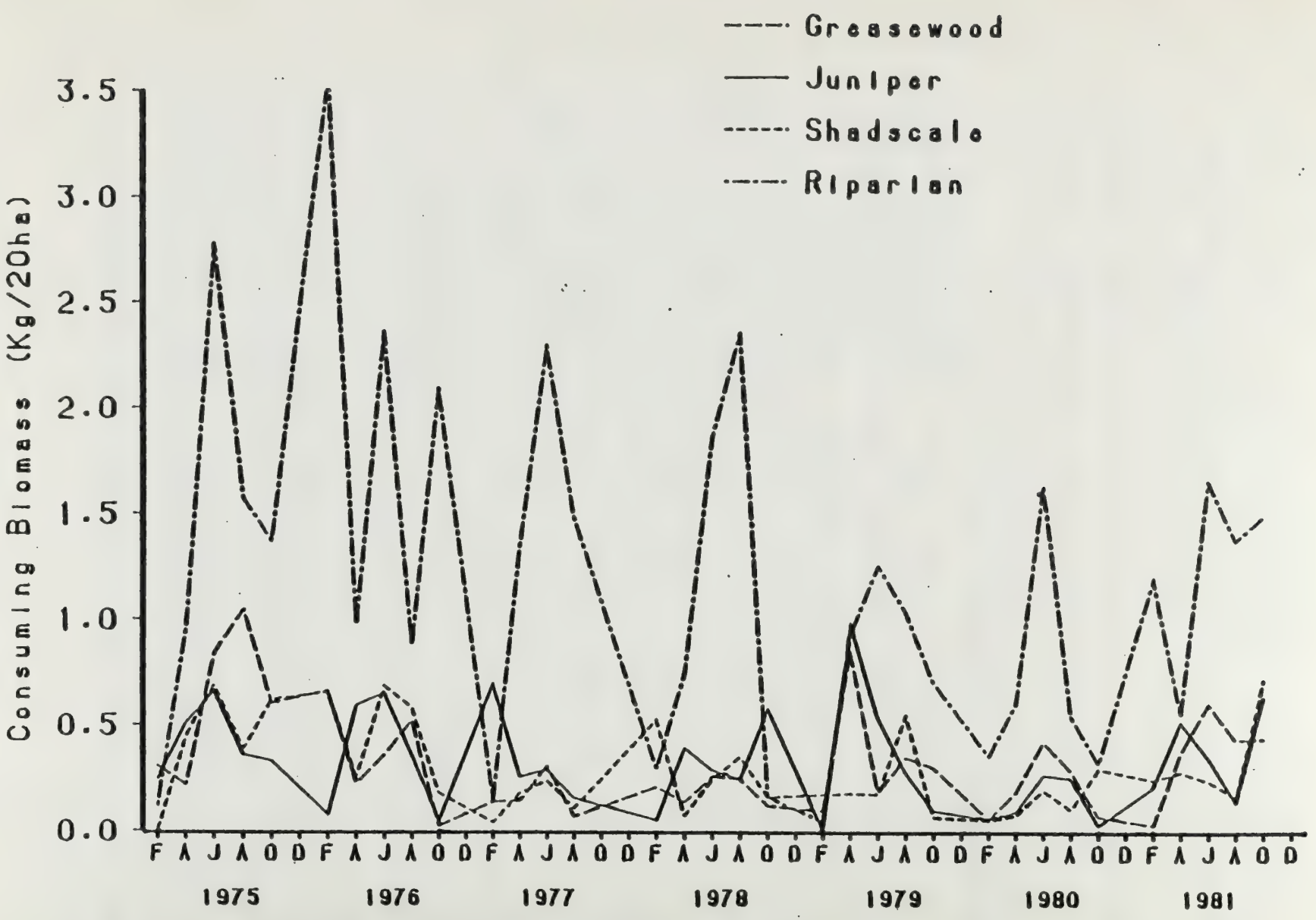

Fig. 4.4-9. Consuming biomass (kg/20 ha) of bird communities in four habitats over a seven-year period.

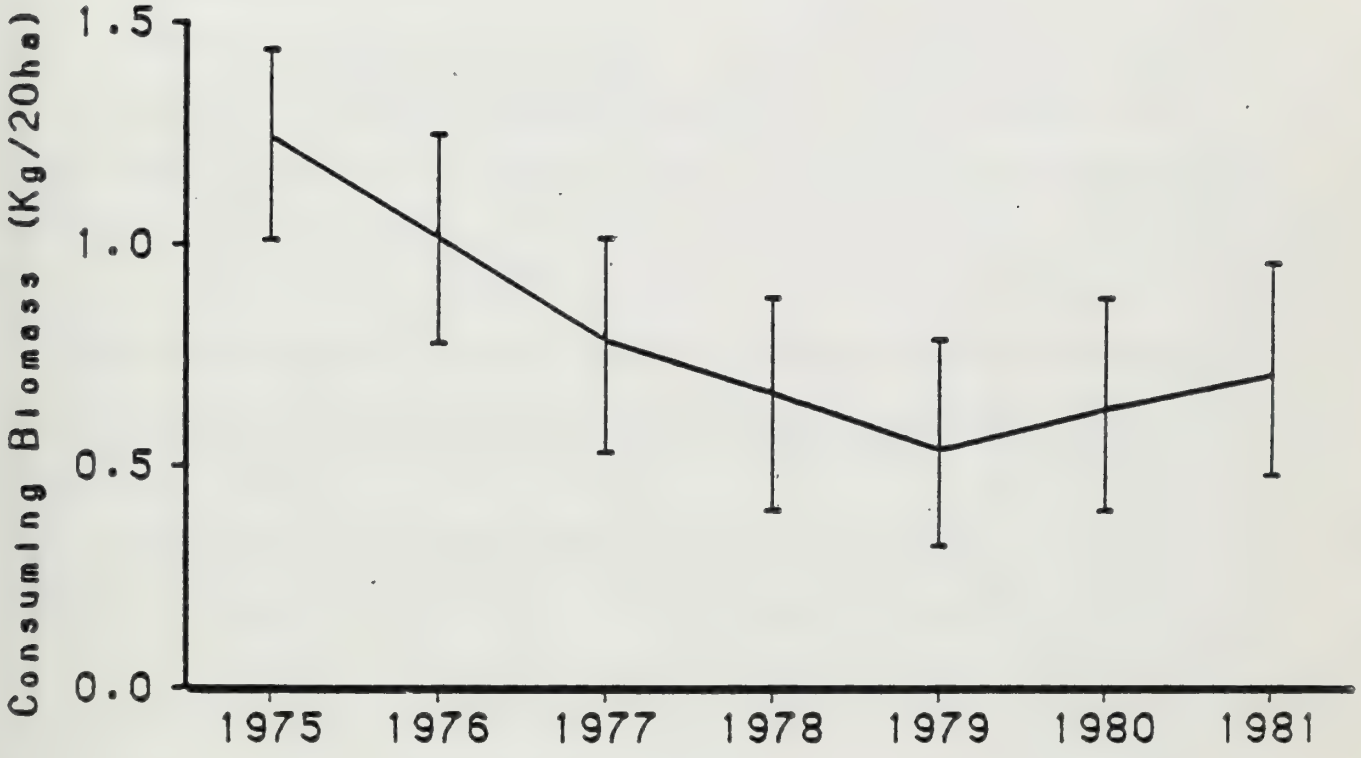

Fig. 4.4-10. June consuming biomass (kg/20 ha) over a seven-year period. This plot is the unweighted mean of the four vegetation types.

Correlations between four resource measures and bird populations (Table 4.4-9) indicate that only spring precipitation was consistently correlated with June consuming-biomass. Although spring precipitation was highly correlated with biomass of annual plants ($r=0.87$, $p<0.01$), annual plant biomass was significantly correlated with only mean bird populations of combined habitats rather than within each habitat. Shrub growth, as measured by sagebrush leader-growth, was correlated with fall and winter precipitation ($r=0.92$, $p<0.05$) and was not closely correlated to bird populations. These data suggest that precipitation affects bird populations during June through an intermediate factor other than that of plant growth.

Table 4.4-9. Correlation coefficients (r) between precipitation or indices of plant growth and bird consuming biomass in June.

	Greasewood	Juniper	Shadscale	Riparian	Mean of all Habitats
Annual precipitation	.04	.58	.21	-.31	-.01
Spring precipitation	.79*	.82*	.83*	.69*	.89**
Biomass of annual plants	.57	.48	.61	.57	.73*
Sagebrush leader-growth	-.17	.48	.41	-	.07

*significant at $p<0.05$
**highly significant at $p<0.01$

Coincident with population changes were changes in the structure of the bird community. Both diversity and richness changed significantly over years when all vegetation types and all months were included (three-way ANOVA, $F_{6,68}=2.66$, $p<0.05$ for diversity, $F_{6,68}=2.73$, $p<0.05$ for richness). Changes in richness and diversity were similar to those in consuming-biomass: a decline from 1975 and 1976 to 1979 and 1980 followed by an increase in 1981.

B. Changes Over Seasons Changes in mean consuming-biomass among seasons were significant ($F_{4,68}=5.21$, $p<0.001$). Three habitats (Greasewood, Juniper and Riparian) exhibited seasonal variation (Fig. 4.4-11), typical of temperate areas, although the peak varied by habitat (April in Juniper, June in Riparian, and August in Greasewood). This interaction between habitat and seasons was significant ($F_{12,68}=2.32$ $p<0.05$). In contrast to the above habitats, Shadscale lacked a breeding season peak and thus exhibited very little seasonal variation in consuming-biomass.

Bird community structure showed a pattern similar to that of consuming-biomass. Both species richness and diversity peaked in June in all four vegetation types (mean of 7 years) except for one instance: diversity in Riparian peaked in August (Fig. 4.4-12). The seasonal variation in richness and diversity was significant ($F_{4,68}=112.4$ and 91.6, $p<0.001$ for both).

C. Differences Among Habitats Differences in community characteristics among habitats were striking: Riparian had the highest density, consuming-biomass, species richness, and species diversity (Fig. 4.4-13, $F_{4,68}=47.5$, 47.9, 95.1 and 24.5, respectively $p<0.001$ for all).

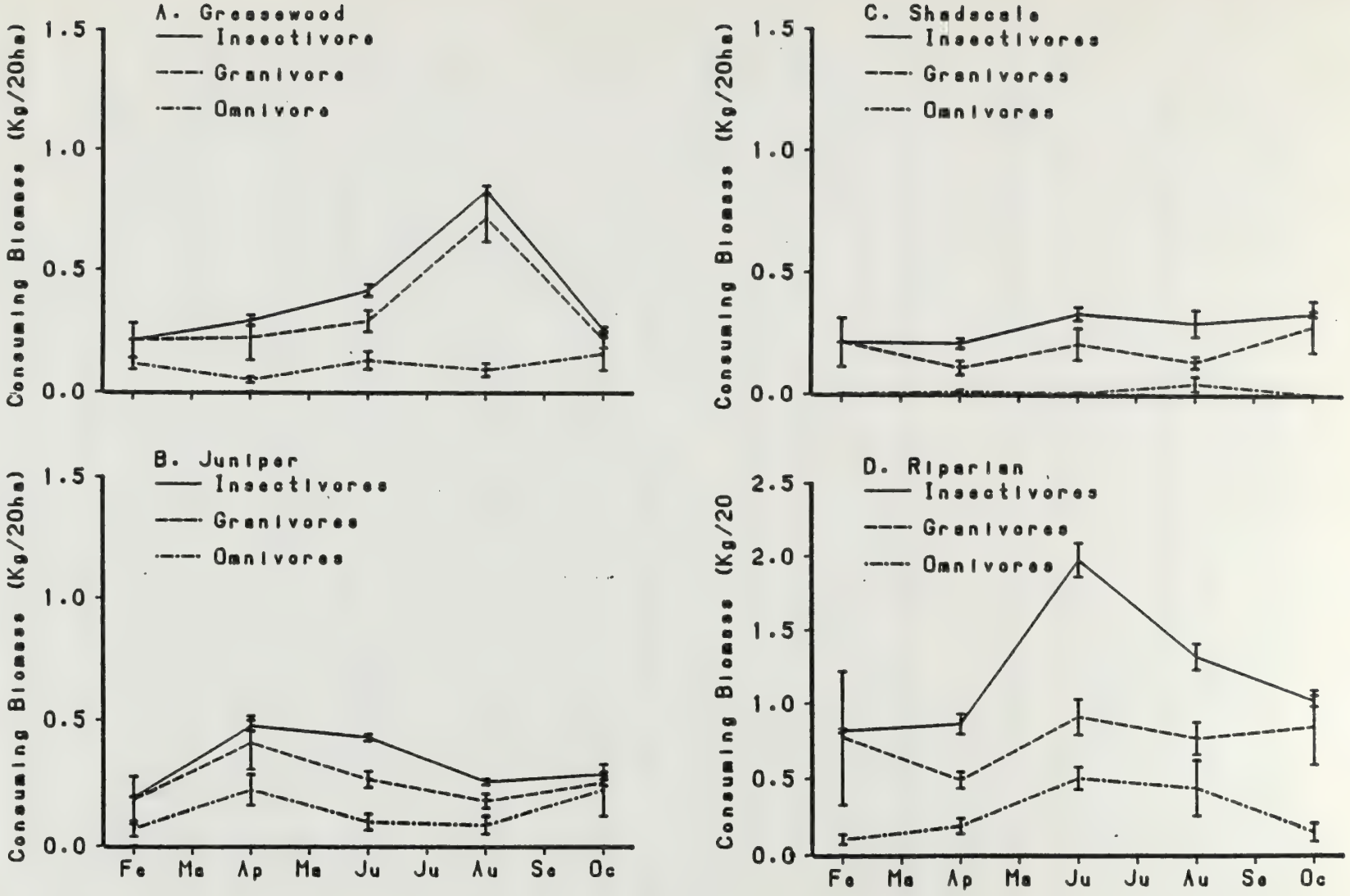

Fig. 4.4-11 Seasonal changes in consuming biomass (kg/20 ha) of three trophic groups. Each line is a cumulative mean of a single group plus all those groups below that line.

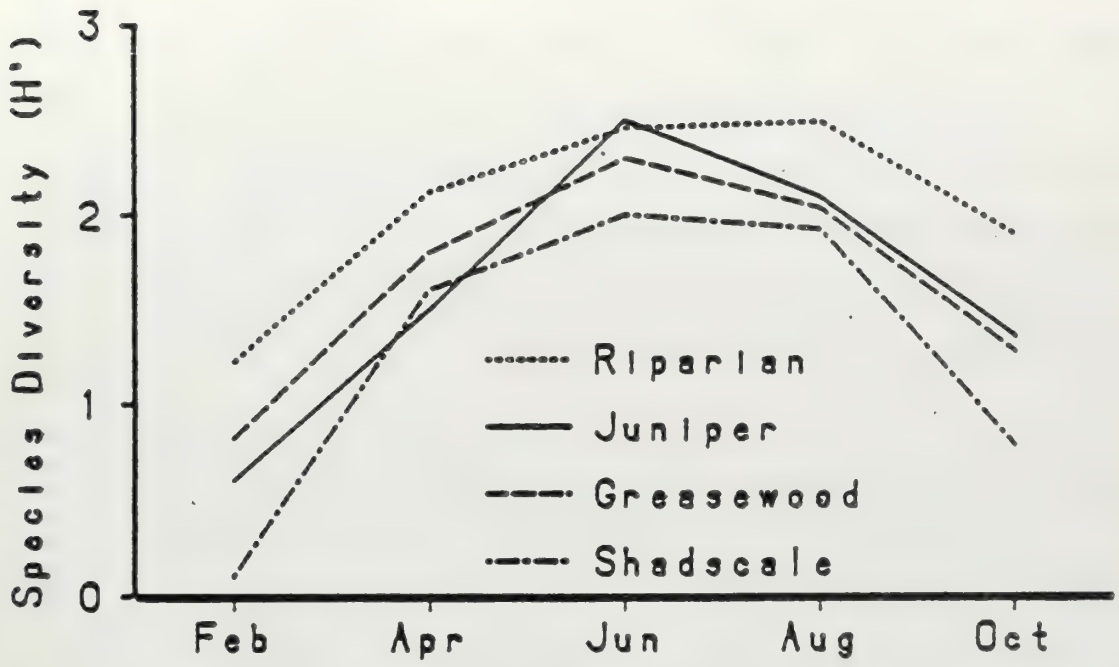

Fig. 4.4-12. Seasonal changes in bird species diversity (H') in four habitats.

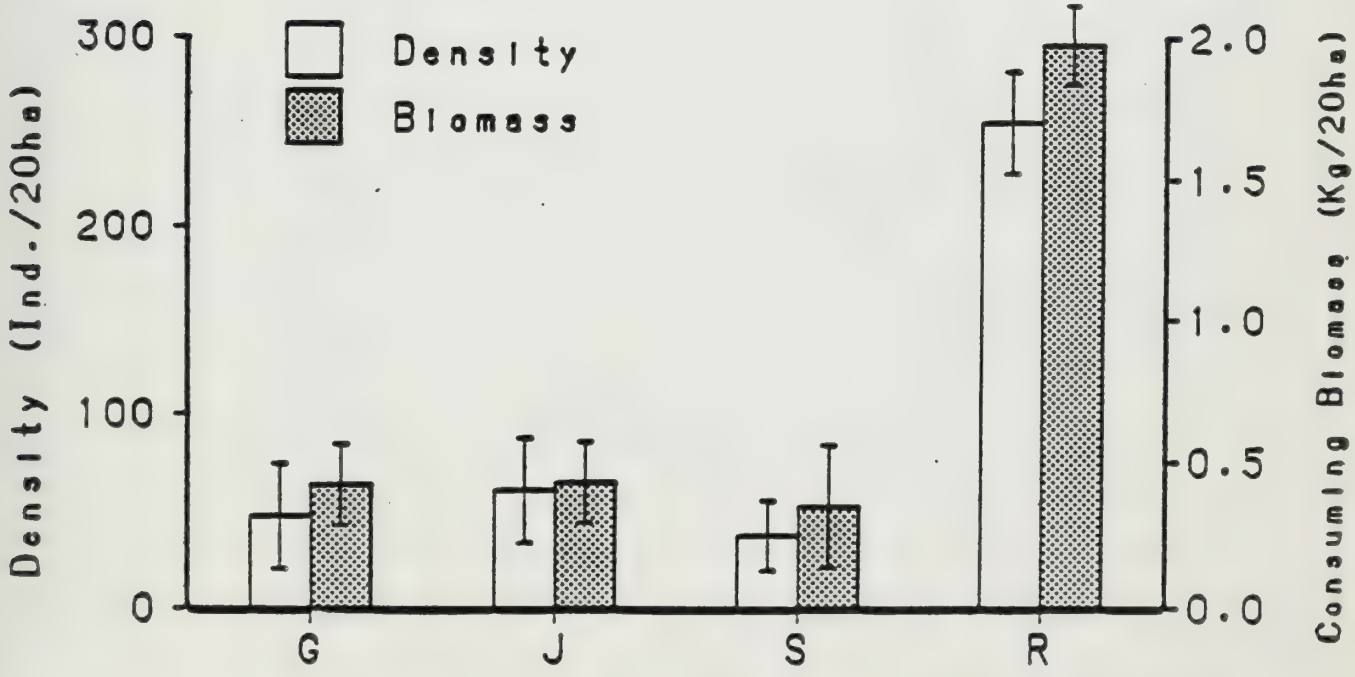

Fig. 4.4-13. Habitat differences in density (ind/20 ha) and consuming biomass (kg/20 ha) among four habitats. G. Greasewood, J. Juniper, S. Shadscale, R. Riparian.

Species richness and diversity in Shadscale was significantly lower than in the other habitats (LSD, $p<0.05$, Steel and Torrie 1960). Similarity in species relative abundance (Table 4.4-10) was high between the two shrub habitats and between Greasewood and Juniper. Riparian was most similar to the other wooded habitat, Juniper, but generally showed low similarity to shrub habitats.

Table 4.4-10. Similarity of June bird communities in four habitats. Similarity indices are means (± standard errors) of indices calculated for each of seven years and are based on species relative abundance.

	Greasewood	Juniper	Shadscale
Juniper	.379±.042		
Shadscale	.428±.037	.190±.023	
Riparian	.133±.025	.199±.041	.079±.021

In this study, four habitat variables were correlated with bird community descriptors (Table 4.4-11). Correlations using only three or four points (habitats) are imprecise, however, some predictive patterns can be seen.

There was a significant correlation between bird consuming-biomass and biomass of annual plants. A significant correlation also existed between physionomic cover diversity and consuming-biomass. Species diversity appeared to be related to three measures of vegetation structure but no correlation was significant. Species richness was correlated most closely to vegetation-diversity measures: foliage-height diversity and physionomic-cover diversity.

Table 4.4-11. Habitat variables and bird community structure in four habitat types and correlations between them. Foliage volume, physionomic cover diversity and foliage height diversity are means of measurements taken during 2 years. All other variables are means over 7 years.

	Habitat Variables				Bird Community Variables		
	Foliage Volume (m^3/m^2)	Physionomic Cover Diversity	Foliage Height Diversity	Biomass Annual Plants (g/m^2)	Consuming Biomass (g/20 ha)	Species Diversity	Species Richness
Greasewood	.20	.71	.59	21.2	424	2.31	19
Juniper	.41	.73	.96	1.8	433	2.50	20
Shadscale	.09	.63	.28	40.1	351	2.00	13
Riparian	---	---	1.36	139.1	1975	2.46	33

	Correlation Coefficient (r)			
	Foliage Volume	Physionomic Cover Diversity	Foliage Height Diversity	Biomass Annual Plants
Consuming Biomass	.82	.99*	.83	.95*
Species Diversity	.95	.98	.87	.17
Species Richness	.84	.99*	.94*	.81

*significant, $p<0.05$

The generally high correlation coefficients in Table 4.4-11 may be partially due to correlations among the bird community variable (e.g., consuming-biomass is correlated with species richness, $r=0.95$, $p<0.05$), or among the habitat variables (e.g., foliage volume and height diversity $r=0.99$, $p<0.05$). Also, several of the correlations may be due to the strong effect of one point (i.e., Riparian) widely separated from a cluster of other points.

4.4.6.3.2 Variation of Functional Groups and Guilds In this section analyses were conducted at two hierarchial levels. First, patterns were examined in three major trophic groups: insectivores (I), omnivores (O) and granivores (G). Second, the six guilds that comprise the insectivore trophic group were examined. Two additional guilds, nectarivores (N) and passerine raptors (R, i.e., shrickes) were also considered.

A. Change over Years There was considerable annual variation in density and consuming-biomass of trophic groups. This variation is illustrated using June consuming-biomass (Fig. 4.4-14).

Relative trophic composition of the communities also changed over years. This was tested by three-way Analysis of Variance among trophic groups, years and habitats using proportions of the community in each group. The significant interaction between trophic proportions and years ($F_{12,63}=3.67$, $p<0.01$) indicates that the relative distribution of avian consuming-biomass among trophic groups changed with each year. The interaction between trophic groups and habitats was also significant ($F_{5,63}=17.74$, $p<0.001$). Interpretation of Fig. 4.4-14 was aided by calculating coefficients of variation. Variation in insectivores was

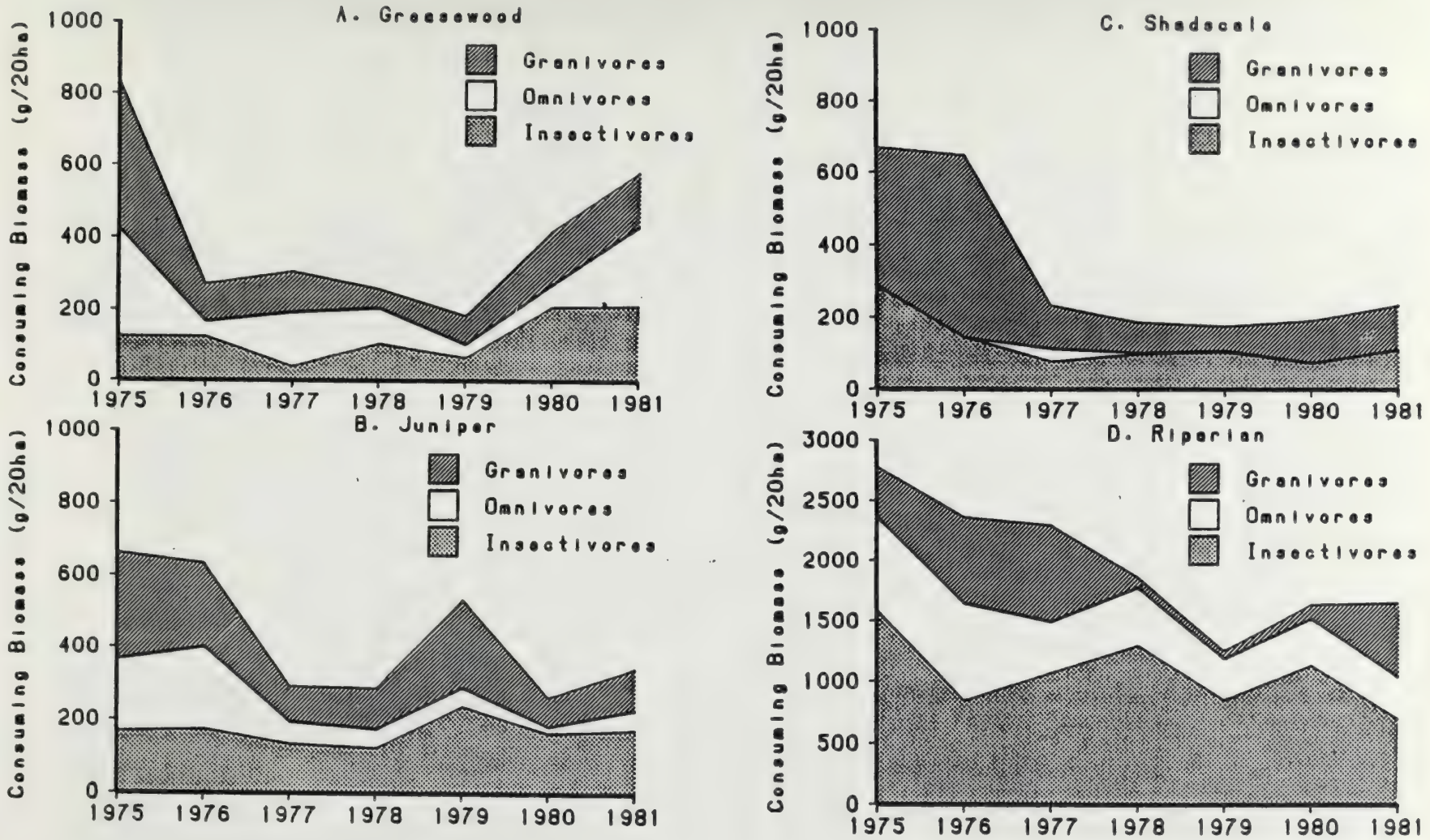

Fig. 4.4-14. June consuming biomass of trophic groups over a seven-year period. A. Greasewood, B. Juniper, C. Shadscale, D. Riparian (note change of scale).

generally low compared to that in both granivores and omnivores. The insectivore trophic group in woody habitats (Juniper, Riparian) varied less than those in shrub communities. Variation of omnivores was least in Riparian, and granivore variation was least in Juniper.

Insectivore guilds differed markedly in their contribution to insectivore consuming-biomass during June (Fig. 4.4-15). Three-way Analysis of Variance showed that insectivore guild composition varied over year ($p<0.05$) and habitats ($p<0.001$).

Granivore and omnivore trophic groups in most habitats were significantly correlated with spring precipitation (Table 4.4-12). Multiple regression analysis combining spring precipitation, plant biomass and sagebrush leader-growth did not explain a significantly greater degree of variation than did spring precipitation alone. Omnivores on Shadscale and granivores in Riparian, did not correlate with spring precipitation. The virtual absence of omnivores on Shadscale (see Table 4.4-14) explains the lack of correlation with spring precipitation. Consuming-biomass of granivores in Riparian was very high in 1977 (a dry year) and fairly low in 1975 (a wet year) showing a trend opposite to other sites, thus the lack of correlation with spring precipitation. This guild pattern in Riparian was for the most part determined by one species: the house finch (Carpodacus mexicanus) (see Table 4.4-13). Excluding the house finch, granivores on Riparian were significantly correlated with spring precipitation ($r=0.78$, $df=5$, $p<0.05$). House finches, which are adapted to arid climate (Salt 1952, Bartholomew and Cade 1956), showed a low correlation with spring precipitation ($r=0.08$, $df=5$) and, since they dominated the guild in Riparian, obscured the

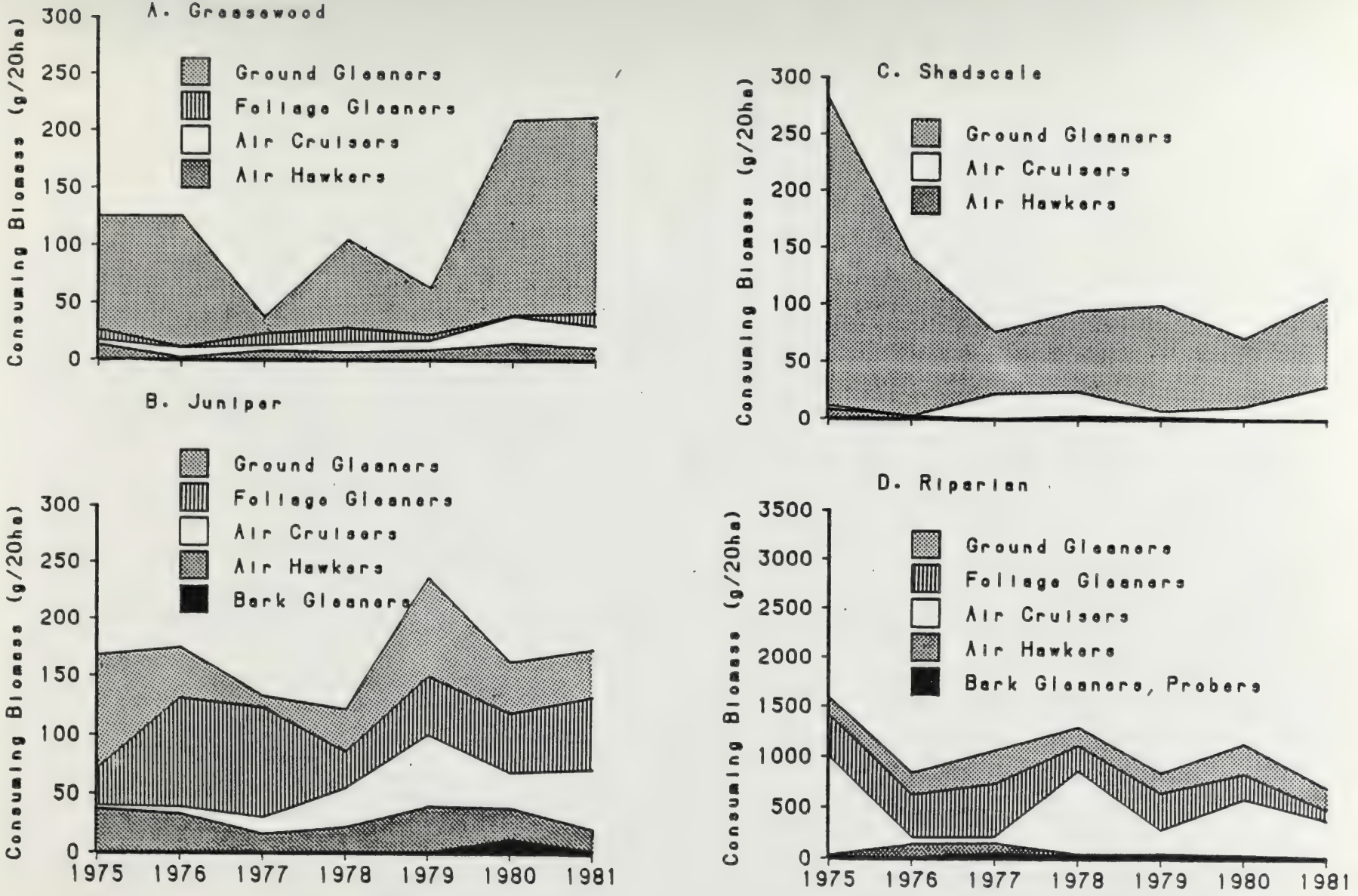

Fig. 4.4-15. June consuming biomass of insectivore guilds over a seven-year period. A. Greasewood, B. Juniper, C. Shadscale, D. Riparian (Note change of scale).

Table 4.4-12. Correlation (r) between trophic group or guild consuming biomass and spring (April to June) precipitation.

Tropic Groups	Guild	Greasewood	Juniper	Shadscale	Riparian
Granivore	GGG	0.91**	0.81*	0.72*	0.33+
Omnivore	GGO	0.67*	0.80*	-0.17	0.72*
Insectivore		0.01	0.22	0.96**	0.36
	ACI	-0.48	-0.50	-0.50	0.30
	AHI	0.07	0.20	0.79*	0.11
	BGI	----	----	----	-0.66
	BPI	----	----	----	-0.31
	FGI	0.07	-0.12	----	0.27
	GGI	0.26	0.64	0.95**	-0.47
	N	-0.19	-0.21	-0.28	0.83**
	R	0.58	----	0.01	----

+without House Finch, correlation is 0.78*, see text.
*$p<0.05$
**$p<0.01$

Table 4.4-13. Density (individuals/20 ha) of ground-gleaning granivores (GGG) in four habitats over seven years arranged by decreasing mean rank. Calculation of ranks is explained in text. Ranks are indices of species dominance in the guild. Vertical bars indicate ranks that are not significantly different at α=0.20.

	1975	1976	1977	1978	1979	1980	1981	Rank
Greasewood								
Amphispiza bilineata	10.6	9.3	13.9	6.2	3.5	6.1	3.7	50.6
Spizella breweri**†	29.3	3.2	0.0	0.3	0.7	3.2	6.2	36.5
Carpodacus mexicanus	1.8	3.6	1.0	0.6	3.8	0.2	0.4	30.7
Chondeste grammacus*	4.1	2.0	0.4	0.0	0.3	2.3	3.7	29.5
Zenaida macroura	2.4	2.0	0.4	0.4	0.2	0.8	1.7	27.1
Spizella passerina	13.4	0.0	0.4	0.0	2.1	2.0	0.0	24.6
Amphispiza belli	0.0	0.4	0.0	0.0	0.6	2.0	1.4	20.3
Zonotrichia leucophrys	0.6	0.0	0.0	0.0	0.0	0.0	0.0	8.6
Juniper								
Carpodacus mexicanus*†	11.0	9.5	2.9	9.4	25.2	3.8	6.2	44.4
Zenaida macroura*	4.4	3.6	1.7	2.2	2.0	0.9	1.0	29.6
Spizella passerina**	10.6	5.3	4.4	0.0	5.2	0.2	1.0	29.4
Amphispiza bilineata *	4.6	6.2	2.2	0.0	0.0	0.0	2.4	23.6
Chondestes grammacus	1.7	3.7	0.0	0.0	0.4	0.7	0.7	19.3
Spizella brewerí	4.7	0.0	0.0	0.0	1.3	0.2	0.0	14.4
Amphispiza belli	0.8	0.0	0.8	0.0	0.0	0.0	0.0	11.6
Shadscale								
Amphispiza belli†	14.0	5.7	2.5	5.9	3.4	11.5	4.1	41.3
Chondestes grammacus *	7.0	10.9	4.2	1.5	2.1	0.6	5.6	35.2
Amphispiza bilineata	5.9	3.7	8.4	2.1	1.7	2.9	2.9	35.0
Zenaida macroura	3.2	12.9	0.0	0.8	0.2	0.4	0.4	21.8
Spizella brewerí	16.4	2.8	0.0	0.0	0.0	0.0	1.8	18.0
Carpodacus mexicanus	0.0	0.4	0.0	0.0	0.7	0.0	0.6	13.3
Eremophila alpestris	0.0	0.4	0.0	0.0	0.3	0.0	0.0	10.4
Riparian								
Carpodacus mexicanus	17.9	59.9	97.4	3.2	2.2	1.1	69.5	51.1
Zenaida macroura*	8.5	7.0	3.2	1.8	2.5	4.3	1.2	41.6
Chondestes grammacus	3.3	13.0	7.5	2.0	0.5	2.2	6.7	40.9
Carduelis tristis	0.0	9.5	4.8	0.0	0.0	0.0	2.7	21.4
Spizella brewerí	9.0	0.0	0.0	0.3	0.0	0.0	0.0	20.6
Spizella passerina	4.1	0.0	1.1	0.0	0.0	0.0	0.0	19.1
Amphispiza bilineata	2.4	0.0	0.0	0.0	0.0	0.0	0.0	16.4
Zonotrichia leucophyrs	0.0	0.0	1.1	0.0	0.0	0.0	0.0	15.5

*correlated with spring precipitation, $p<0.05$; **$p<0.01$
†correlated with annual plant biomass, $p<0.05$; ††$p<0.01$

Table 4.4-14. Density (individuals/20 ha) of ground-gleaning omnivores (GGO) in four habitats over seven years arranged by decreasing mean rank. Ranks are indices of species dominance in the guilds. Vertical bars indicate ranks that are not significantly different at $\alpha 0.20$.

	1975	1976	1977	1978	1979	1980	1981	Rank	
Greasewood									
Gymnorhinus cyanocephalus	8.0	1.2	5.5	0.8	0.9	3.2	10.7	37.7	▌
Pica pica	1.0	0.4	1.8	3.0	0.8	0.0	0.5	29.1	▌
Pipilio erythrophthalmus	0.0	0.8	0.0	0.0	0.0	0.0	0.4	17.2	▐
Euphagus cyanocephalus	7.5	0.0	0.0	0.0	0.0	0.0	0.0	15.6	▐
Agelaius phoeniceus	1.2	0.0	0.0	0.0	0.0	0.0	0.0	14.9	▐
Aphelocoma coerulescens	0.0	0.0	0.0	0.2	0.0	0.0	0.0	14.6	▐
Juniper									
*Gymnorhinus cyanocephalus**	6.0	8.5	0.6	0.8	0.5	0.8	0.3	34.1	▌
*Pica pica**	1.9	1.6	0.4	0.8	0.3	0.2	1.5	30.4	▌
Molothrus ater	1.5	1.8	0.0	0.0	2.9	0.0	0.8	23.4	▌
Euphagus cyanocephalus	0.8	0.0	2.6	0.0	0.0	0.0	0.0	16.0	▐
Corvus corax	0.0	0.1	0.0	0.2	0.0	0.0	0.0	13.5	▐
Aphelocoma coerulescens	0.3	0.0	0.0	0.0	0.0	0.0	0.0	11.6	▐
Shadscale									
Euphagus cyanocephalus	0.3	0.0	0.0	0.3	0.0	0.0	0.0	12.0	▐
Gymnorhinus cyanocephalus	0.0	0.0	1.8	0.0	0.0	0.0	0.0	10.5	▐
Pica pica	0.0	0.0	0.0	0.0	0.2	0.0	0.0	10.5	▐
Riparian									
Molothrus ater	14.7	24.5	20.0	17.7	17.8	7.7	4.7	62.9	▐
*Pipilio erythrophthalmus***	33.4	30.4	7.5	4.3	7.5	13.7	17.4	62.1	▐
Pica pica	5.9	5.2	3.3	7.6	2.2	3.2	1.0	50.1	▐
*Passerina amoena***†	18.8	5.2	1.1	0.0	0.0	1.6	12.1	48.7	▐
Guiraca caerulea	0.0	1.7	0.0	0.0	0.2	2.7	0.0	27.7	▐
Euphagus cyanocephalus	0.0	0.5	0.7	1.0	0.0	0.0	0.0	26.6	▐
Gymnorhinus cyanocephalus	0.0	1.0	0.4	0.0	0.0	0.0	0.0	22.9	▐
Passerina cyanea	0.0	0.0	0.0	0.0	0.0	0.0	1.3	21.0	▐
Melospiza melodia	0.0	0.0	1.1	0.0	0.0	0.0	0.0	20.6	▐
Agelaius phoeniceus	0.0	0.5	0.0	0.0	0.0	0.0	0.0	19.6	▐

*correlated with spring precipitation, $p<0.05$; **$p<0.01$
†correlated with annual plant biomass, $p<0.05$; ††$p<0.01$

relationship between spring precipitation and other member species of the guild.

The only insectivore guilds that were significantly correlated with spring precipitation were ground-gleaning and air-hawking insectivores on Shadscale. The latter guild was poorly represented in this habitat except during the very wet spring of 1975. For air-hawkers this site appears to be marginal and occupied only under optimal conditions.

Why granivores and omnivores are highly correlated with spring precipitation but insectivores are not is unclear. One striking difference between these groups is their use of foraging substrates. Most insectivore guilds forage on above-ground substrates (shrubs, trees and air) whereas omnivores and granivores forage primarily at ground level. Spring precipitation and its high correlation with annual plant biomass is probably a better index of habitat quality at ground level than above ground level.

Nectarivores, which were uncommon in all habitats, were positively correlated with spring precipitation ($r=0.83$, $df=5$, $p<0.001$) and annual plant biomass ($r=0.60$, $df=4$, $p<0.10$) on Riparian. Nectarivores were regularly observed in Riparian only during the wet years of 1975 and 1976.

Loggerhead shrikes (Lanius ludovicianus), the only breeding member of the taxonomically-restricted raptor guild, were highly correlated with cricetid rodent density on Greasewood ($r=0.87$, $df=5$, $p<0.05$) and Shadscale ($r=0.58$, $df=5$, $p<0.10$). Shrikes were rarely observed in Juniper and Riparian.

B. Changes Over Seasons In addition to marked yearly variation, there is also a great deal of seasonal variation in trophic group

consuming-biomass (see Fig. 4.4-11). Seasonal variation within habitats, as measured by coefficients of variation was relatively low for granivores (mean CV - 45.8%) but high for insectivores (mean CV - 79.5%) and omnivores (mean CV - 73.4%). High coefficients of variation for monivores and insectivores indicate a high degree of seasonality for these groups, due primarily to high seasonality of invertebrates.

Seasonal occurrence was highly variable for most insectivore guilds, especially air cruisers and air hawkers. The least variable guilds were bark probers, bark gleaners (except on Greasewood where they were rare), and ground gleaners. Foliage gleaners were less variable in evergreen types, than in the deciduous Riparian vegetation or Greasewood and Juniper vegetation in Shadscale where they occurred irregularly.

Seasonal changes in consuming-biomass of ground and foliage insectivores corresponded closely to changes in invertebrate biomass (g/m^2) in Juniper (Fig. 4.4-16). In the shrub communities, Greasewood and Shadscale, correspondence was good from summer through fall but not in spring. There was poor agreement between invertebrate biomass and insectivore consuming biomass in Riparian because of the lack of an invertebrate biomass estimate for cottonwood trees. It is not known if these correlations represent cause/effect relationships or if they result from a similar response to seasonal changes in environment by both insectivores and invertebrates.

C. Differences Among Habitats To examine relative differences in habitat use by trophic groups, evenness (J') of each trophic group across habitats was calculated. A high evenness-index indicates little difference in the importance (i.e., consuming-biomass) of a group among the

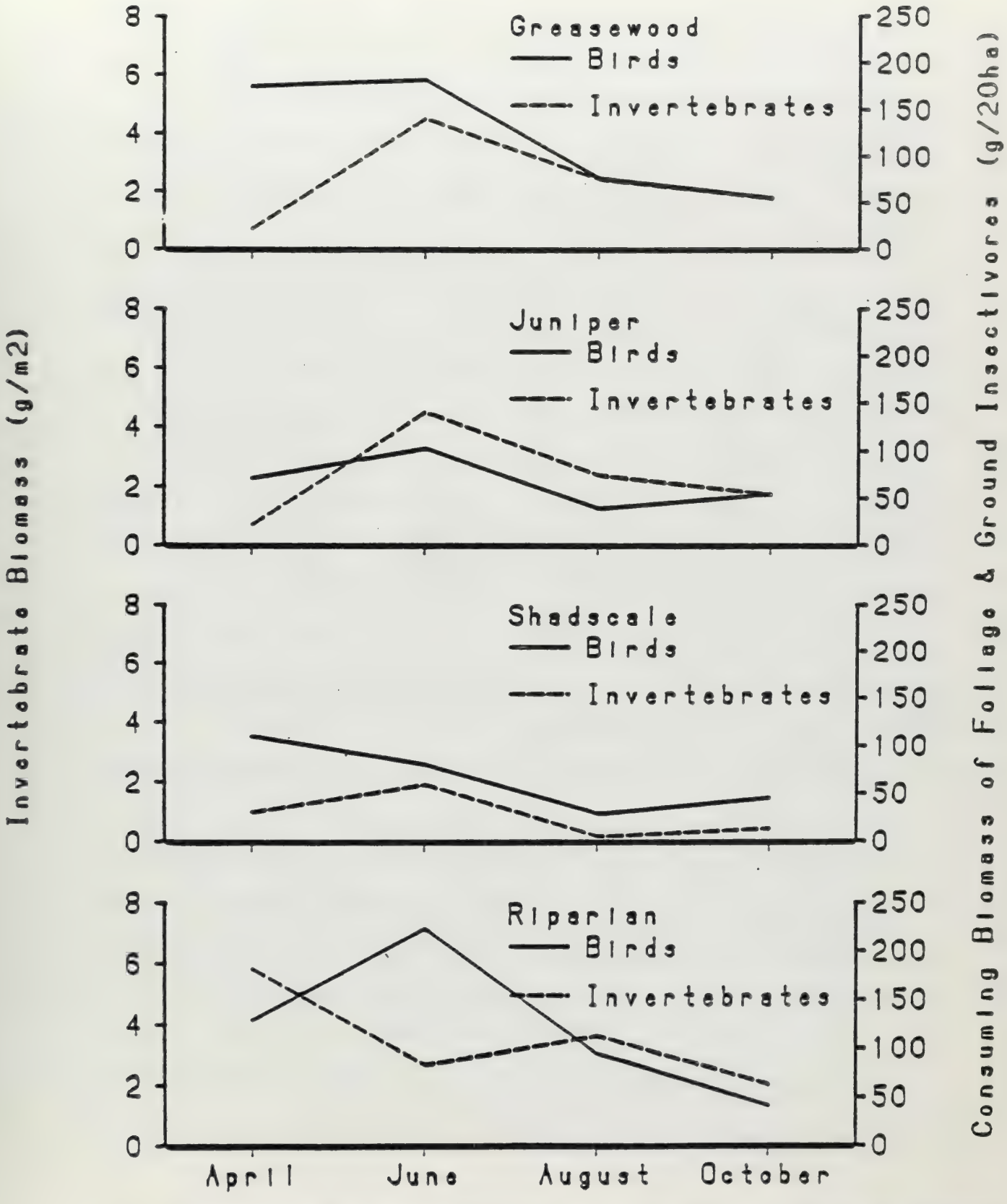

Fig. 4.4-16. Seasonal changes in invertebrate biomass (g/m^2) on shrubs and consuming biomass of foliage and ground insectivores (g/20 ha) in four habitats. See text for further details.

the four habitats. During June, the granivore trophic group was evenly distributed over habitats (J'=0.94) compared to omnivore (J'=0.63) and insectivore (J'=0.65) groups. All groups reached their highest consuming-biomass in Riparian, but omnivore and insectivore consuming-biomass was 3.9 and 6.4 times higher, respectively, in Riparian than in any other habitat.

For insectivore guilds, habitat evenness during June was high only for ground gleaners (J'=0.90) and air hawkers (J'=0.68) but low for air cruisers, bark gleaners, and foliage gleaners (J'<0.35 for all).

Habitat differences in consuming-biomass of ground-gleaning and foliage-gleaning insectivores corresponded well to differences in invertebrate biomass based upon four sampling periods from April through October, 1981 ($r=0.92$, $df=2$, $p<0.05$; Fig. 4.4-17). For the four sample periods taken separately, there was fair correspondence between these insectivores and invertebrate biomasses in June ($r=0.60$, $p<0.20$) and good correspondence in August ($r=0.99$, $p<0.05$) but poor correspondence during April ($r=0.18$) and October ($r=0.20$).

In summary, granivores as a group were characterized by relatively even distribution over habitats and by exhibiting low seasonality but having considerable variability from one year to the next. Insectivores were the least variable group over years but had marked seasonality and low habitat evenness. Omnivores, with characteristics of both groups, had marked seasonaltiy, much annual variability, and low habitat evenness.

Insectivore guilds were characterized as follows. Air-cruising insectivores exhibited much annual and seasonal variability in

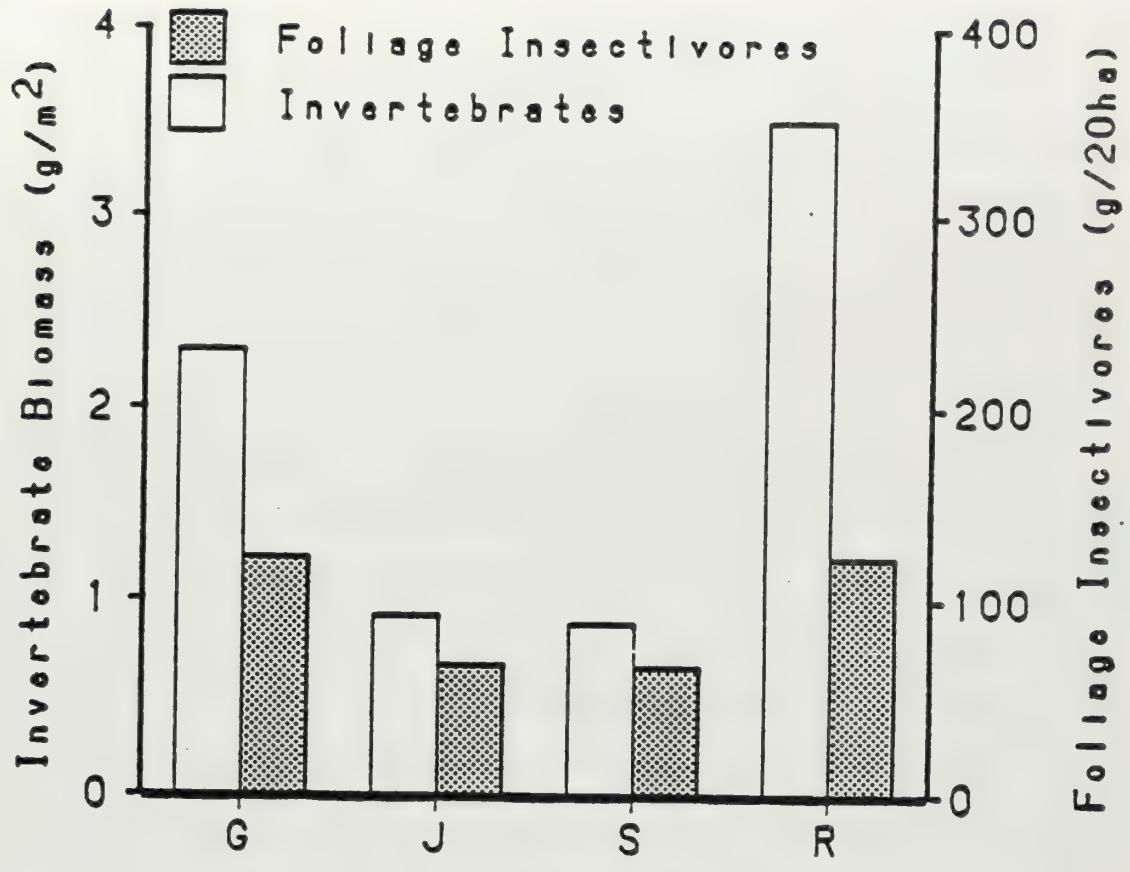

Fig. 4.4-17. Mean invertebrate biomass (g/m^2) and consuming biomass of foliage and ground insectivores (g/20 ha) in four habitats. G. Greasewood, J. Juniper, S. Shadscale, R. Riparian. See text for further details.

consuming-biomass and were unevenly distributed over the four habitat types. Air- hawking insectivores varied little from year to year and were relatively evenly distributed over habitats but showed much variation over seasons. Bark-probing and bark-gleaning insectivores exhibited high annual variability, low seasonal variability, and low habitat evenness. Foliage gleaners had very low annual variation but were uneven in habitat usage. Seasonality in the foliage-gleaning guild was less

pronounced in habitats dominated by evergreen plants. Ground-gleaning insectivores exhibited high annual variation (except in Riparian), little seasonal variability and relatively even habitat occupancy.

Nectarivores and raptors (i.e., shrikes) were characterized by high annual and seasonal variability. Nectarivores were rather evenly distributed over habitats but shrikes, which occurred in predominantly shrub communities, had low evenness.

4.4.6.3.3 Variation Within Guilds To further explain changes in guilds detailed above, temporal and spatial patterns of guild structure and composition were searched for probable causes for these patterns.

A. Granivores Granivorous birds (e.g., sparrows, doves) varied widely in population density among habitats and years. Species composition of the granivore guild for the four habitats was quite similar (Table 4.4-13). Of ten granivorous species, five were common to all habitats and two were found in three habitats. The American goldfinch (Carduelis tristis) was the only highly-ranked species restricted to one habitat. Despite this high similarity, the ranking of species in each habitat differed markedly. For example, species-rank order in Juniper was nearly the opposite of that in Shadscale. The house finch (Carpodacus mexicanus), the highest ranking guild member in Juniper, was nearly the lowest in Shadscale. Only the black-throated sparrow (Amphispiza bilineata) was among the three highest ranking species in Greasewood and Shadscale, the two shrub communities. The sage sparrow (A. belli), which ranked first in Shadscale, ranked seventh in Greasewood. Juniper and Riparian had the most similar rankings. Differences in species rank reflect marked differences in species habitat selection.

Changes in population density over years were in some cases correlated with changes in environmental conditions. There were 20 cases (see Table 4.4-13) of species declining in population density from 1975- 1976 (wet years) to 1977-1978 (drought years) but only four cases of species increasing in population density. Three of the latter cases were for black-throated sparrows (two sites) and house finches. Population densities of seven of the sixteen highest ranking species (four from each habitat) were significantly correlated with spring precipitation ($0.69< r<0.90$; $df=5$, $p<0.05$). These high correlations suggest that many species respond numerically to changes in habitat quality.

Considerable variation in guild structure occurred over seasons. Riparian was the only habitat where species were shared between winter (February) and summer (June and August). The granivore guild in all habitats was present in all seasons but was represented by different species.

B. Omnivores The omnivore guilds in Greasewood and Juniper were quite similar: each contained six species and was dominated by pinon jays (Gymnorhinus cyanocephalus) and black-billed magpies (Pica pica) (Table 4.4-14). Most other guild members were infrequent. In Shadscale the guild contained only three species, all of which occurred in both Greasewood and Juniper. These three species were infrequent in Shadscale and during three years (1976, 1980, 1981) the guild was not represented at all. The omnivore guild in Riparian contained ten species, five of which were shared with Greasewood and Juniper. Only the scrub jay (Aphelocoma coerulescens), rarely observed in the latter habitats, failed to be recorded in Riparian. Brown-headed cowbirds (Molothrus ater) and

rufous-sided towhees (Pipilio erythropthalmus) dominated the guild in Riparian and magpies were also consistently recorded.

June densities of the eight most dominant species (two each from Greasewood and Juniper, four from Riparian) were compared with spring precipitation, annual plant biomass and sagebrush leader-growth. Pinon jays and magpies in Juniper were significantly correlated with spring precipitation ($r=0.70$ and 0.82, respectively, $df=5$, $p<0.05$) as were rufous-sided towhees and lazuli buntings on Riparian ($r=0.88$ for both, $df=5$, $p<0.01$). Only lazuli buntings were significantly correlated with annual plant biomass ($r=0.78$, $df=5$, $p<0.05$) and no species was significantly correlated with sagebrush leader-growth.

C. Air-cruising Insectivores Species composition of this guild was similar across habitats, as expected for these wide-ranging species, but patterns in dominance-rank differed markedly between the Riparian and the other three habitats. No species was strongly dominant in Greasewood, Juniper, or Shadscale and even the most highly-ranked species (common nighthawks [Chordeiles minor] and white-throated swifts [Aeronautes saxatalis] were absent or uncommon in most years. Each of these three habitats had one or two inconsistent species and two or three infrequent species. In Riparian, cliff swallows (Petrochelidon pyrrhonota) were strongly dominant accounting for 80.0 to 99.7% of guild density each year. Cliff swallows were infrequent guild members in other habitats.

All guild members exhibited much between-year variation in population density. The cliff swallow in Riparian is the only species for which temporal variation was sufficiently documented to address potential causes of population change. Maximum rate of streaflow in the White

River, which usually occurred in late May or early June (coincident with spring snow melt), was significantly correlated with cliff swallow density ($r=0.77$, $df=5$, $p<0.05$). High streamflow results in flooding of low areas creating breeding areas for insects, a potential food source.

Seasonal changes in air-cruising insectivores were large. This guild was poorly represented in April and absent in October and February.

D. Air-hawking Insectivores Species richness of the air- hawking guilds was nine in Riparian, five in Juniper, four in Greasewood and two in Shadscale. With two exceptions, poorwill (Phalaenoptilus nuttallii) and the accidental eastern phoebe (Sayornis phoebe), all species found in Greasewood, Juniper and Shadscale were also found in Riparian. This guild was characterized by lack of strong dominance on all sites except Juniper where gray flycatchers (Empidonax wrightii) were consistently the most common species. Say's phoebe (Sayornis saya) and gray flycatchers were co-dominants on Greasewood. Surprisingly, there were no consistent species on Riparian. Four inconsistent species shared dominance on Riparian and five species were rare. Air-hawking insectivores were poorly represented in Shadscale. Relationships between members of the air-hawking guild and resource levels were essentially absent.

E. Bark-gleaning Insectivores Bark-gleaning insectivores were absent in Shadscale and infrequent in Greasewood due to the lack of appropriate foraging substrates. Bewick's wren (Thryomanes bewickii) was the only species recorded in Juniper. This species and the house wren (Troglodytes aedon) were the only species recorded in Riparian during June. The house wren was the only species regularly recorded in Riparian

during June (5 of 7 Years). Breeding density of house wrens was not significantly correlated with any measure of habitat quality.

F. Bark-probing Insectivores Bark probers were recorded only in Riparian. Downy woodpeckers (Picoides pubescens) and hairy woodpeckers (P. villosus) were permanent resident but neither species consistently dominated the guild. Breeding densities of bark-probing insectivores did not appear to be affected by either drought or very moist conditions. This may be due to the fact that cottonwood and other riparian trees are phreatophytes, deriving their water from the water table. Therefore, riparian trees, and consequently many of the resources the trees provide, are to some degree independent of rainfall.

G. Foliage-gleaning Insectivores Foliage-gleaning insectivores were rich in Riparian (20 species) poorly represented in Greasewood and Juniper (7 species each) and all but absent in Shadscale (1 species). Guild composition in both Greasewood and Juniper was quite similar, owing largely to the presence of scattered junipers on the greasewood site, but these habitats differed considerably in guild structure (Table 4.4-15).

The foliage-gleaning guild in Riparian was dominated by six species. In addition, five inconsistent and nine infrequent species occurred in Riparian. Only three foliage-gleaning species were seen in other habitats and not in Riparian: plain titmouse, Scott's oriole (Icterus parisorum) and common bushtit (Psaltriparus minimus).

None of the nine most dominant foliage-gleaning species (three from Juniper, six from Riparian) was significantly correlated with resource abundance measures. In Riparian, where cottonwood and other phreatophytes account for the vast majority of foliage, a lack of significant

Table 4.4-15 Density (individuals/20 ha) of foliage-gleaning insectivores (FGI) in four habitats over seven years arranged by decreasing mean rank. Ranks are indices of species dominance in the guild. Vertical bars indicate ranks that are not significantly different at α=0.20.

	1975	1976	1977	1978	1979	1980	1981	Rank
Greasewood								
Dendroica nigrescens	0.0	0.3	0.8	0.4	0.3	0.0	0.4	34.9
Parus inornatus	0.9	0.0	0.4	1.5	0.0	0.0	0.0	28.1
Icterus parisorum	0.0	0.0	0.0	0.0	0.4	0.0	0.4	24.4
Polioptila caerulea	0.0	0.0	1.3	0.0	0.0	0.2	0.0	23.9
Myiarchus cinerascens	0.0	0.0	0.0	0.2	0.0	0.0	0.7	23.4
Polioptila melanura	0.6	0.0	0.0	0.0	0.0	0.0	0.0	20.6
Piranga ludoviciana	0.3	0.0	0.0	0.0	0.0	0.0	0.0	19.9
Juniper								
Dendroica nigrescens	7.2	7.6	10.0	1.4	10.8	2.8	9.1	43.3
Polioptila caerulea	0.0	4.1	9.2	2.2	2.4	7.7	5.1	36.1
Parus inornatus	0.0	7.7	2.3	2.9	0.0	1.5	0.6	29.7
Myiarchus cinerascens	0.0	0.0	1.0	0.0	0.0	0.2	0.3	18.8
Piranga ludoviciana	0.4	0.0	0.0	0.0	0.0	0.0	0.3	17.2
Polioptila melanura	0.4	0.0	0.0	0.0	0.0	0.0	0.0	15.2
Psaltriparus minimus	0.0	0.5	0.0	0.0	0.0	0.0	0.0	14.7
Shadscale								
Myiarchus cinerascens	0.0	0.0	0.0	0.0	0.0	0.0	0.3	4.0
Riparian								
Dendroica petechia	27.1	25.9	39.2	23.5	25.1	19.5	5.6	136.4
Polioptila caerulea	3.0	9.6	12.2	5.3	2.2	5.2	6.4	119.6
Icterus galbula	2.1	8.5	11.4	6.6	10.2	0.8	2.1	114.4
Icteria virens	6.5	8.9	7.4	5.3	8.4	2.6	0.4	113.7
Parus atricapillus	3.0	0.7	1.6	1.3	0.6	5.2	5.7	37.4
Myiarchus cinerascens	2.0	1.6	5.5	0.4	1.1	6.1	0.7	35.7
Piranga ludoviciana	2.5	3.2	4.3	0.0	1.6	1.2	0.0	31.3
Pheucitus melanocephalus	6.5	1.7	0.0	0.0	1.6	2.7	0.0	72.7
Vireo gilvus	1.0	3.0	1.6	0.4	1.1	0.0	0.0	68.8
Vireo solitarius	2.0	0.0	2.1	1.3	0.0	0.0	0.0	57.7
Vermivora virginiae	6.0	0.0	0.0	0.0	2.2	0.0	0.0	54.3
Dendroica coronata	0.5	2.2	0.0	0.0	0.0	0.0	0.0	54.1
Vermivora celata	1.0	0.0	0.0	0.4	0.6	0.0	0.0	50.1
Vireo olivaceus	0.5	0.0	0.0	0.0	0.0	0.0	0.7	46.9
Geothlypis trichas	0.5	1.5	0.0	0.0	0.0	0.0	0.0	45.0
Polioptila melanura	4.0	0.0	0.0	0.0	0.0	0.0	0.0	43.6
Wilsonia pusilla	2.5	0.0	0.0	0.0	0.0	0.0	0.0	42.4
Dendroica nigrescens	0.0	1.5	0.0	0.0	0.0	0.0	0.0	40.1
Oporornis tolmiei	0.0	0.7	0.0	0.0	0.0	0.0	0.0	38.2
Coccyzus americanus	0.0	0.0	0.4	0.0	0.0	0.0	0.0	37.1

relationships between foliage-insectivore density and spring rainfall is not surprising. However, this explanation does not account for the lack of significant relationships in Juniper. In fact, the pattern of breeding density of several species is the opposite of the expected. Six species in Riparian and three species in Juniper showed peaks in density during 1977, a drought year.

The foliage-gleaning guild was characterized by marked seasonal changes in species richness. For example, in Riparian, species richness numbered one in February, seven in April, twenty in June, fifteen in August and eight in October. In contrast to the granivore guild there are no foliage-gleaning species that consistently occur as spring or fall migrants which do not also breed. In Juniper, dominance changed markedly with season. The migratory black-throated gray warblers, the most dominant species in June, were rare in April and August. In February, April and October, the guild was dominated by the plain titmouse (a permanent resident), and in August, by this species and blue-gray gnatcatcher. In Riparian the situation was more complex. Blackcapped chickadee was the only permanent resident in Riparian and was always among the three most-dominant resident in Riparian and was always among the three most-dominant species in the non-breeding seasons. The other most-dominant species included yellow-rumped warblers in April and October, blue-gray gnatcatchers in April and August, yellow warblers in August, and ruby--crowned kinglets (Regulus calendula) in October.

H. Ground-gleaning Insectivores Species richness of ground-gleaning insectivores was highest in Greasewood (nine), intermediate in Juniper and Riparian (seven) and lowest in Shadscale (five) (Table 4.4-16).

Table 4.4-16. Density (individuals/20 ha) of ground-gleaning insectivores (GGI) in four habitats over seven years arranged by decreasing mean rank. Ranks are indices of species dominance in the guild. Vertical bars indicate ranks that are not significantly different at α=0.20.

	1975	1976	1977	1978	1979	1980	1981	Rank	
Greasewood									
Salpinctes obsoletus	4.8	2.3	1.5	2.7	4.4	10.4	2.0	56.4	▌
Sialia currucoides	1.4	0.0	0.0	7.1	1.4	8.4	1.1	43.7	▌
Sturnella neglecta	2.9	3.0	0.0	0.0	0.0	1.1	8.2	39.4	▌
Colaptes auratus	0.0	0.3	0.3	0.0	0.0	0.0	0.0	27.8	▌
Mimus polyglottos	0.0	3.4	0.0	0.0	0.0	0.0	0.0	25.6	▌
Sialia mexicanus	0.6	0.0	0.0	0.0	0.0	0.0	0.0	24.1	▌
Sturnus vulgaris	0.0	0.0	0.0	0.0	0.0	1.1	0.0	23.9	▌
Oeroscoptes montanus	0.0	0.0	0.0	0.0	0.3	0.0	0.0	23.7	▌
Catherpes mexicanus	0.3	0.0	0.0	0.0	0.0	0.0	0.0	23.4	▌
Juniper									
*Salpinctes obsoletus**	7.2	4.1	0.7	3.1	4.9	2.7	4.4	45.0	▌
Sialia currucoides†	5.3	0.0	0.3	1.8	6.8	2.7	0.6	36.0	▌
Catherpes mexicanus	0.0	0.0	0.7	0.0	0.0	0.0	1.0	21.3	▌
Colaptes auratus	0.0	0.7	0.0	0.1	0.0	0.0	0.0	19.6	▌
Sturnella neglecta	0.1	0.0	0.0	0.0	0.0	0.0	0.3	19.2	▌
Sturnus vulgaris	0.0	0.0	0.0	0.0	0.0	0.2	0.0	17.0	▌
Oreoscoptes montanus	0.4	0.0	0.0	0.0	0.0	0.0	0.0	16.9	▌
Shadscale									
*Sturnella neglecta*** ††	11.9	6.5	1.7	2.4	3.4	2.0	3.9	29.8	▌
Salpinctes obsoletus	2.6	0.3	2.6	3.7	4.9	2.0	1.2	25.9	▌
Oreoscoptes montanus††	2.3	1.7	0.3	0.6	0.2	1.1	0.0	17.1	▌
Sialia currucoides	1.7	0.0	0.0	0.0	0.2	0.0	0.0	9.3	▌
Colaptes auratus	0.0	0.0	0.3	0.0	0.0	0.0	0.0	7.9	▌
Riparian									
Turdus migratorius	2.8	4.3	9.6	8.1	2.4	5.7	3.2	39.7	▌
Colaptes auratus	1.1	1.3	5.5	2.5	4.2	1.9	0.5	31.0	▌
Sturnus vulgaris	3.5	4.3	1.1	0.0	2.8	4.2	0.5	28.9	▌
Salpinctes obsoletus	1.6	7.8	0.7	0.3	0.0	1.6	17.3	28.1	▌
Sialia currucoides	0.0	1.1	0.0	0.0	0.0	6.9	4.7	18.6	▌
Sturnella neglecta	2.1	0.0	2.2	0.0	0.0	1.5	0.4	17.9	▌
Catharus ustulata	0.0	0.0	0.0	0.0	1.1	0.0	0.0	10.9	▌

*correlated with spring precipitation, $p<0.05$; **$p<0.01$
†correlated with annual plant biomass, $p<0.05$; ††$p<0.01$

In contrast, the number of consistent species was highest in Riparian (four), intermediate in Juniper and Shadscale (two) and lowest in Greasewood (one). This guild was quite similar in Greasewood and Juniper.

Annual variation in species populations, for this guild as well as for the others, was quite high. Of the eleven most dominant species (two each from Greasewood and Juniper, three from Shadscale and four from Riparian) only rock wrens in Juniper ($r=0.89$, $df=5$, $p<0.05$), and western meadowlarks ($r=0.97$, $df=5$, $p<0.05$) and sage thrashers ($r=0.94$, $df=5$, $p<0.05$) in shadscale were significantly correlated with spring precipitation. Only two of these species, mountain bluebirds ($r=0.94$, $df=5$, $p<0.05$) on Juniper and western meadowlarks ($r=0.97$, $df=5$, $p<0.05$) on Shadscale, were significantly correlated with annual-plant biomass.

4.4.6.3.4 Aquatic Birds Sixteen species of aquatic birds were recorded on the study site. Of these, thirteen were transients, primarily visiting the area during spring migration. Two species, killdeer (Charadrius vociferus) and spotted sandpiper (Actitus macularia), were summer residents and the Canada goose (Branta canadensis) was a permanent resident. The high proportion of transients (81% of species) suggests that there is very little suitable breeding habitat for aquatic birds on the study site.

Density of aquatic birds varied markedly over both seasons and years. In 1975 through 1979, aquatic birds were most common in April (2.7 to 3.4 ind/river km), the spring migration period. Density of aquatic birds decreased during June (0.5 to 2.6 ind/river km) and August (0.1 to 2.2 ind/river km) and were usually uncommon or absent in February

and October. In 1980 and 1981, seasonal patterns were similar to that described above, except that no migratory peak occurred in April.

4.4.6.3.5 Raptors Fourteen hawks and four owl species were encountered on the study site. Among the hawks, six were permanent residents, two were summer residents, three were winter visitors and three were irregular transients.

The three most common and widespread species of hawks were golden eagle (Aquila chrysaetos), red-tailed hawk (Buteo jamaicensis), and American kestrel (Falco sparverius). Golden eagle populations were fairly stable, averaging 0.05 ind/km during April and June. In winter (February) eagle populations were more conspicuous (0.11 ind/km) than during spring, due to breeding and nest building activities. Golden eagle abundance was not significantly correlated with cottontail populations ($r=0.09$).

Red-tailed hawks and American kestrels were much more common in spring and summer than in fall or winter. Red-tailed hawk populations were significantly correlated ($r=0.88$, $df=5$, $p<0.01$) with cottontail populations (Section 5.5) over the seven years. Kestrels showed little correlation with one of their primary food sources, cricetid rodents ($r=0.01$ in Greasewood, $r=0.24$ in Shadscale).

Two endangered hawk species occurred near the tracts. Bald eagles (Haliaeetus leucocephalus) were common winter (February) visitors and were seen most frequently in the cottonwood bottoms along the White River. These eagles were recorded during February observations five of seven years at an abundance of approximately one individual to every three for four river km.

Peregrine falcons (Falco peregrinus) were rare transients on the study site. Peregrines were sighted in April and August of 1975 and have not been recorded since. During one of these earlier sightings, an adult peregrine was observed feeding a juvenile.

4.4.6.4 Discussion Avian community characteristics varied markedly from 1975-1981 at the study site. An analysis of the trophic structure of the community (trophic groups and guilds) also indicated much variability which, in many cases, did not reflect trends observed at the community level. Rather, each trophic group and guild had a unique pattern of change. Species densities within guilds also varied over a wide range and again, density changes were frequently contrary to guild patterns. Thus, at all levels of resolution, variation appears to be the rule rather than the exception.

Striking differences in the pattern of change among trophic groups, guilds and species suggest that these patterns are unlikely to be caused by a single, or even a small set, of environmental factors. Instead, numerous biotic and abiotic factors were involved. Four potential causes of change have been recognized.

First, measures of food resources are likely to explain the most variability in bird communities. However, in environments characterized by high climatic variability, such as those considered here, correlations between consumers and resources may not be easily tracked. Second, events outside the breeding season and, for migrant species, conditions in wintering areas or on migratory routes may influence population dynamics, overriding the effects of food resources during the breeding season. Third, other resources (e.g., nest sites, cover, free water) may

limit populations so that bird species are not able to track food resources. Fourth, a certain amount of stochastic variation is inherent in populations. The problem is to separate stochastic variation, which is poorly understood, from other causes of variation.

Our search for causes of community variability addressed primarily the importance of food resources and other measures of habitat quality on the site. These are factors which are most likely to be impacted by oil shale development.

Annual precipitation showed no correlation with yearly changes in the total community or in guilds. The lack of relationship is because much of the annual precipitation in the Uinta Basin falls during the winter in the form of snow. Much of the snowcover melts and runs off during winter and early spring, before plants are physiologically capable of absorbing it. Thus, most annual precipitation is not translated into food resources (seeds, insects) for birds. However, annual precipitation may be an important factor influencing bird populations in grasslands.

Spring precipitation was highly correlated with yearly changes in the community, granivore, and omnivore guilds and a few of the insectivore guilds. Spring precipitation may occur as rain or snow and occurs at a time when plants are becoming physiologically active. In fact, since summers in the Uinta Basin are characteristically hot and dry, plants inhabiting the region have growth patterns adapted to spring precipitation. The causal pathway between spring precipitation and certain bird populations presumably lies in the relationships between spring precipitation, plant productivity and the consequent production of food resources (e.g., seeds and invertebrates). However, most bird

populations showed no correlation with two indices of plant production (see below).

The fact that most insectivore guilds had no significant correlation with spring precipitation was surprising. Two factors distinguish insectivores from other trophic groups. First, insectivores, which were common only in Juniper and Riparian, foraged primarily on arboreal substrates. Second, insectivore populations remained relatively stable during the course of this study, not responding to either drought or wet years. One possible cause for the differences among guilds may be that the deep-rooted trees (cottonwood and juniper) on which most insectivores forage are, to some deree, independent of spring precipitation. This is particularly true of the pheatophytic cottonwood. If this is the case, insects living on these plants may also be little influenced by spring precipitation.

The effect of spring precipitation on ground-foraging birds is especially evident when comparing avian populations between 1975 with a very wet spring, to 1977, one to the most severe drought years of this century. In the spring on 1975 a desert bloom occurred with annual plant production an order of magnitude greater than normal on some sites. Bird populations reached peak abundance at this time. In 1977, annual-plant biomass was so meager that it could not be accurately sampled and was recorded as zero. Many bird species that were common in 1975 were absent in 1977 and total population density in 1977 dropped to less than half the 1975 level.

Bird populations should be affected by annual-plant biomass, through two pathways: (1) seed production; and (2) invertebrate abundance; both

parallelling annual-plant productivity. There were no significant correlations found between the granivore guild and annual-plant biomass and only three granivore species were significantly correlated with annual-plant biomass (Table 4.4-13). Hill (1980) found that changes in bird populations parallelled changes in net production of annual plants and shrubs (but see Wiens and Rotenberry in press). Grant and Grant (1980) found that bird populations responded to the availability of seeds. Raitt and Pimm (1976) concluded that sheet-flow following precipitation events increased the availability of seeds by concentrating them along the edges of playas where they were more efficiently exploited by birds. In some situations, however, spring precipitation may cause seeds to germinate and thus deplete seeds available to birds (Ward 1971).

Total abundance of the ground-gleaning insectivore and ground-gleaning omnivore guilds had low correlation with annual-plant biomass, which would indicate invertebrate abundance at ground level and only one omnivore species and three ground-insectivore species were significantly correlated with annual-plant biomass. Similarly, Raitt and Pimm (1976) found that insectivore abundance was less clearly related to food supplies than were granivores and raptors. Sagebrush leader-growth had no clear correlation with abundance of any guild and appears to be a poor indication of habitat quality for birds.

The lack of correlation with plant production indices could be due to one or two explanations. First, our measures of plant production may not relate to food resources available to birds either because plant production is not reflected in seed or invertebrate production or because

seeds or invertebrates produced are not available to birds. Second, bird populations on our site may be below carrying capacity and thus are not forced to respond to changes in resource abundance (Wiens and Rotenbery in press).

Differences in bird community-structure among habitats were related to vegetation structure. Avian consuming-biomass was significantly correlated with physiognomic-cover diversity and annual-plant biomass while species richness was correlated with physiognomic-cover doversity and foliage-height diversity. Bird species diversity was positively correlated with foliage volume, physiognomic-cover diversity and foliage-height diversity but these correlations fell short of significance at the a=0.05 level. Tomoff (1974) found that physiognomic-cover diversity was a better predictor of bird-species diversity than was foliage-height diversity in arid desert-shrub habitats.

Increased vegetation complexity may cause an increase in bird species richness, diversity, and consuming biomass for a number of reasons. Structurally more complex habitats are usually more productive, providing greater food resources. Invertebrate abundance may have been important in determining insectivore density in the four habitats. Greater plant productivity, however, only helps to explain the increase in total bird density or consuming biomass but not the increase in species richness and diversity. Increased structural complexity of the vegetation is associated with both a greater variety of food types available and a wider variety of substrates where food types can occur. Holmes et al. (1979) explained this relationship by stating that a

greater variety of substrates allowed birds to specialize their foraging repertoire resulting in partition of food resources among more species.

In general our results aligned well with some aspects of bird community theory but not with others. Bird density appeared to be influenced by some measures of resource abundance but not with others. Bird community structure reflected habitat structure, but not in a way that was entirely consistent with the findings of others. We expect that departures from bird community theory may reflect the difficulty in generalizing over areas of widely differing vegetation, climate or topography.

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4.4.7 Mammals

4.4.7.1 Introduction The two objectives of the faunal baseline study on the Tracts Ua and Ub are to establish sound procedures for monitoring impacts and for guiding effective reclamation of disturbed lands. To achieve these objectives five criteria were set for wildlife: species inventory, temporal distribution, spatial distribution, abundance, and ecological relationships. These criteria were met by an inventory of all the terrestrial fauna, temporally through all seasons during seven years, spatially in four main vegetation types and numerically through techniques appropriate for measuring changes in abundance. Ecological relationships were largely dependent on concurrent information collected by other disciplines working on the Tracts Ua and Ub.

Mammal population dynamics are examined from four points of view. First, yearly population changes as they are influenced by yearly environmental change. Second, seasonal dynamics emphasizing the seasonal activity patterns of the mammals and the variabiity in these patterns between years. Third, differences among mammal communities in four vegetation types. Finally, population and community dynamics of selected species.

Three groups of mammals, distinguished by three different sampling techniques, are rodents, diurnal (including crepuscular) mammals, and bats. Besides using taxonomic groupings, mammals are also considered by trophic groups - herbivores, granivores, insectivores, carnivores and omnivores.

4.4.7.2 Methods Mammal populations were sampled using three procedures: (1) live trapping grids for rodents (nocturnal mammals); (2) line transects for diurnal mammals; and (3) mist nets for bats. Rodent trapping grids were estalished near line transects (Fig. 5.0-1) and trapping was conducted each August from 1975 through 1981 and in October 1981. Trap grids were 12 x 12 arrays (144) covering 2.72 ha with traps 15 m apart. Sherman live traps were opened and baited with rolled oats or barley each evening and checked and closed each morning for five consecutive days. For each animal captured, species, age, sex, reproductive condition, physical condition, trap number and any identifying marks were recorded. Weights were determined to the nearest gram. All animals were individually marked and released.

Density from the 12 x 12 grids was calculated according to the formula: $D = n/A$ where D = density, n = number of individuals trapped, A = area of grid (hectares).

Rodents were also trapped along each line transect in February, April, June, August and October. The following trapping regimes were used: (1) 2 x 12 array, 15 m apart, 1975-1976; (2) 5 x 5 array, 15 m apart, 1977-1979; (3) 1 x 25 array, 40 m apart, 1980; (4) 1 x 25 array, 15 m apart, 1981; and (5) 1 x 12 array, 15 m apart, with 2 traps per station, 1981. These varied trapping regimes were attempts to find an efficient method that correlated well with density estimates from the trapping grids (see Section 4.4.8). Other trapping procedures, i.e., baiting, weighing, etc., were identical to those used on trapping grids. Abundance from transect trapping was calculated as individuals trapped per 100 trap nights.

Diurnal mammals were censused by walking line transects in the evening, starting two hours prior to sunset and ending one hour after sunset. Abundance from transects was calculated as individuals observed per km of transect.

Bats were mist-netted (1977-1980) at a pond located 7 km south of the White River in Asphalt Wash. The banks of the pond were covered with thick bulrush (Scirpus spp) and surrounded by alrge greasewood (Sarcobatus vermiculatus). Artesian flow from an abandoned natural gas well supplied the pond. Two 2.1 x 5.5 m mist nets with 13 mm mesh were positioned 15 cm above the water. Nets were opened prior to sunset (2100 in June, 2000 in August) and remained open until 0400 (MDT). Mist nets were open for five consecutive nights in 1977-1980. One session was missed in 1977 due to flash floods hindering access to the pond. Abundance from mist-netting was calculated as individuals captured per trap night.

Each bat captured was identified to species and weighed to the nearest gram. Time of capture was recorded and forearm, wing width and length were measured to the nearest mm. Each bat captured was sexed, marked to identify recapture, and released.

The overall mammal species inventory and habitat distribution was based on sightings and signs (e.g., tracks, scats) on and near the tracts. Identifications were based on Armstrong (1970) and Durrant (1952). Species richness (i.e., the number of species) was based on transect observations and trapping. Similarity indices were applied only to the rodent community and not the mammal community data drom transects. This was due to the dominance of one mammal on transects which resulted in high similarities among and within all vegetation communities.

Species richness, diversity, density, abundance, similarities and biomass were expressed as mean $\pm$ standard error of the mean. All statistical comparisons were based on 2-way (years versus seasons) or 3-way (years versus seasons versus vegetation communities) Analysis of Variance with mean comparisons ranked according to Least Significant Difference (Steel and Torrie 1960). ANOVA's were calculated by the Rummage program (Bryce 1980). Simple linear regressions and correlations were calculated according to Steel and Torrie (1960) and were tested by t-values. Any relationship not accompanied by a signficance level but reported in the text was considered biologically significant but lacked statistical significance at $p<0.05$.

4.4.7.3 Results and Discussion Forty-three species from six Orders make up the mammal community found on Tracts Ua and Ub (Table 4.4-17). The most diverse taxonomic group of mammals is the rodents. The other Orders, in order of decreasing species richness, are Chiroptera, Carnivora, Artiodactyla, Lagomorpha, and Perissodactyla.

These species were divided into five trophic groups: herbivores, insectivores, carnivores, omnivores and granivores. The hares and rabbits (Lagomorpha), ungulates (Artiodactyla and Perissodactyla) and a majority of the rodents (Rodentia) comprise the herbivorous trophic group. Bats (Chiroptera) make up the insectivorous trophic group. Canids, mustelids and felids (Carnivora) comprise the flesh-eating trophic group and the squirrels (Rodentia) are considered omnivores. The family Heteromyidae comprise the granivorous trophic group, the seed-eaters.

Table 4.4-17. Taxonomic and functional distribution of forty-three mammals inhabiting the Utah Oil Shale Tracts, Ua and Ub, Uintah County, from 1975 through 1981

MAJOR TAXA	HABITATS				Total Species
	Greasewood	Shadscale	Juniper	Riparian	
Rodentia	12	12	14	17	20
Chiroptera	*	*	*	9	9
Carnivora	5	3	4	5	7
Artiodactyla					
Wild	1	2	1	2	2
Domestic	2	2	1	2	2
Lagomorpha	2	2	2	1	2
Perissodactyla					
Domestic	1	1	1	1	1
TOTAL SPECIES	23	22	23	37	43
MAJOR TROPHIC GROUP					
Herbivores (including domestic livestock)	12	14	13	19	20
Insectivores	*	*	*	9	9
Carnivores	5	3	4	5	7
Omnivores	4	3	4	5	5
Granivores	2	2	2	2	2
TOTAL SPECIES	23	22	23	37	43

*not sampled

A. Changes Over Years Mammal populations fluctuated widely over the course of the study. Densities of herbivorous rodents (Cricetidae) increased dramatically in 1976 and decreased even more dramatically in (Table 4.4-18). Densities remained low through 1979 then increased to a median level in 1980 and 1981. Biomass (kg/ha) and richness (number of species) were closely correlated with density ($r=0.98$, $p<0.01$, and and $r=0.90$, $p<0.01$, respectively). A marked decrease in diversity (H') demonstrated that the drought in 1977 drastically affected the rodents'

Table 4.4-18. Annual density, biomass, species richness and species diversity of rodents from 1975 through 1981. Comparisons below each column show significant differences ($p<0.05$) between years.

YEARS	DENSITY (Ind/ha)	BIOMASS (kg)	RICHNESS (No. of Spp)	DIVERSITY (H')
1975(1)	18.0±3.6*	2.2±0.5	5.5±0.5	1.35±0.12
1976(2)	39.1±3.6	3.9±0.8	7.5±1.0	1.36±0.24
1977(3)	5.2±1.5	0.6±0.2	2.8±0.8	0.73±0.26
1978(4)	9.3±2.0	1.0±0.2	4.8±0.5	1.21±0.21
1979(5)	8.3±0.6	0.8±0.1	3.5±0.5	0.90±0.20
1980(6)	20.2±4.4	1.8±0.5	4.5±0.3	1.06±0.12
1981(7)	18.7±2.2	2.1±0.3	6.0±1.0	1.20±0.27
	1,3,4,5,6,7 < 2 3,4,5 < 1,6,7	1,3,4,5,6,7 < 2 3,4,5 < 1,7 3 < 6	1,3,4,5,6,7 < 2 3,5,6 < 7 3,5 < 1 3 < 4,6	3,5, < 1,2 3 < 4,7

*Standard Error of the Mean

community structure as well as their population density. The drought caused both short-term and long-term extinctons for some nocturnal omnivores (Sciuridae) and herbivores (Cricetidae). No appreciable effect, however, was detected among granivores (Heteromyidae). The

The increased density among the rodents in 1980 was due primarily to the granivores. Herbivore abundance increased slightly in 1980 and 1981 whereas omnivores showed no signs of increase until 1981.

In 1975 and 1976 abundance of diurnal mammals followed the same pattern as the densities of rodents (Table 4.4-19). Although the drought caused a significant decrease in diurnal mammals's abundance in 1977 ($p<0.05$), the lowest abundance was not reached until 1979 following a severe winter, and showed no indications of recover in 1981.

Fluctuations in diurnal mammal abundance are due primarily to changes in desert cottontail (Sylvilagus audubonii) abundance. From 1975 to 1978,

Table 4.4-19. Annual abundance, biomass, species richness and species diversity of diurnal mammals from 1975 through 1981. Comparisons below each column show significant differences ($p \leq 0.05$) between years.

DIURNAL MAMMALS

YEARS	ABUNDANCE (No/km)	BIOMASS (kg/km)	RICHNESS (No. of Spp)	DIVERSITY (H')
1975(1)	1.7±0.3*	18.3±12.5	2.1±0.4	0.46±0.09
1976(2)	5.7±1.1	17.6±5.6	2.8±0.2	0.36±0.06
1977(3)	3.3±0.3	19.6±4.6	2.5±0.3	0.33±0.08
1978(4)	2.2±0.4	19.8±8.4	2.3±0.2	0.26±0.08
1979(5)	0.2±0.08	3.2±2.2	1.4±0.3	0.03±0.03
1980(6)	0.3±0.09	7.6±3.6	1.5±0.2	0.18±0.08
1981(7)	0.4±0.09	6.1±3.4	1.6±0.2	0.29±0.08
	1,3,4,5,6,7 < 2 1,4,5,6,7 < 3 5,6,7 < 1,4	5 < 1,2,3,4	1,5,6,7 < 2 5,6,7 < 3,4 5 < 1	5 < 1,2,3,4,7 6 < 1,2 4 < 1

*Standard Error of the Mean

79% of the diurnal mammals counted on transect were cottontails. From 1979 to 1981 they made up 27% of count. The low and variable counts of the other diurnal mammals merely suggested that abundance had decreased or increased but these changes were not statistically significant.

Biomass of diurnal mammals remained consistent from 1975 to 1978, then declined significantly ($p<0.05$). Due to the extremely high variability of encountering the large diurnal mammals (20-85 kg), biomass showed no correlation with abundance. Nevertheless, biomass as well as species richness and diversity suggests that the drought, its after-effects, and a severe winter in 1978-1979 played a significant role in the 1979 decline in diurnal mammals.

Most of the diurnal mammals counted on transects were herbivorous. Only twice during seven years was a carnivore encountered on transect. Omnivores and insectivores were also infrequently seen compared to herbivores.

One major group of mammals, domestic livestock, were out of synchrony with population trends of other mammals. The lack of synchrony with livestock is due to consistent grazing pressure from year to year regardless of range conditions. The same number of sheep (Ovis aries) forage in the upland shrub and juniper habitats from December through April and the same number of cattle (Bos taurus) forage in Riparian habitat and greasewood draws from late June through October each year. The effect of livestock on wild herbivores is undetermined.

Bat abundance, biomass, richness and diversity also appeared to be depressed by the 1977 drought (Table 4.4-20). However 1977 results were not significantly lower than the means of 1979 through 1980. In 1978, when the rodents remained at low densities and the diurnal mammals were

Table 4.4-20. Annual abundance, biomass, species richness and species diversity of bats from 1977-1980. Comparisons below each column show significant differences ($p \leq 0.05$) between years.

	BATS			
YEARS	ABUNDANCE (Ind/Trap Night)	BIOMASS (kg/Trap Night)	RICHNESS (No. of Spp)	DIVERSITY (H')
1977 (1)	8.4±2.3*	0.09±0.02	3.0±0.5	0.86±0.15
1978 (2)	24.8±3.0	0.33±0.06	5.2±0.3	1.32±0.07
1979 (3)	11.2±3.4	0.19±0.07	3.6±0.5	0.90±0.13
1980 (4)	14.4±2.2	0.20±0.03	4.2±0.5	1.12±0.15
	1,3,4 < 2	1 < 2	1,3,4 < 2	1,3,4 < 2

*Standard Error of the Mean

declining in abundance, bat populations peaked. A comparison of these annual changes in abundance among the three mammal categories (Fig. 4.4-18) suggested that the bat's food resources had no apparent relationship to vegetative productivity. Annual abundance in bats was closely correlated with annual abundance of aerial-feeding insectivorous birds ($r=0.97$, $p<0.01$) from 1977 to 1980. The abundance of aerial-feeding birds through seven years was significantly correlated with the quality of spring runoff along the White River which may increase invertebrate production in the Riparian habitat. This, however, does not explain bat use in the pond which is not affected by the spring runoff. It may be that the pond is more important to the bats as a source of water during their upland foraging and that they, like the aerial-feeding birds, may be dependent on invertebrate production in Riparian habitat.

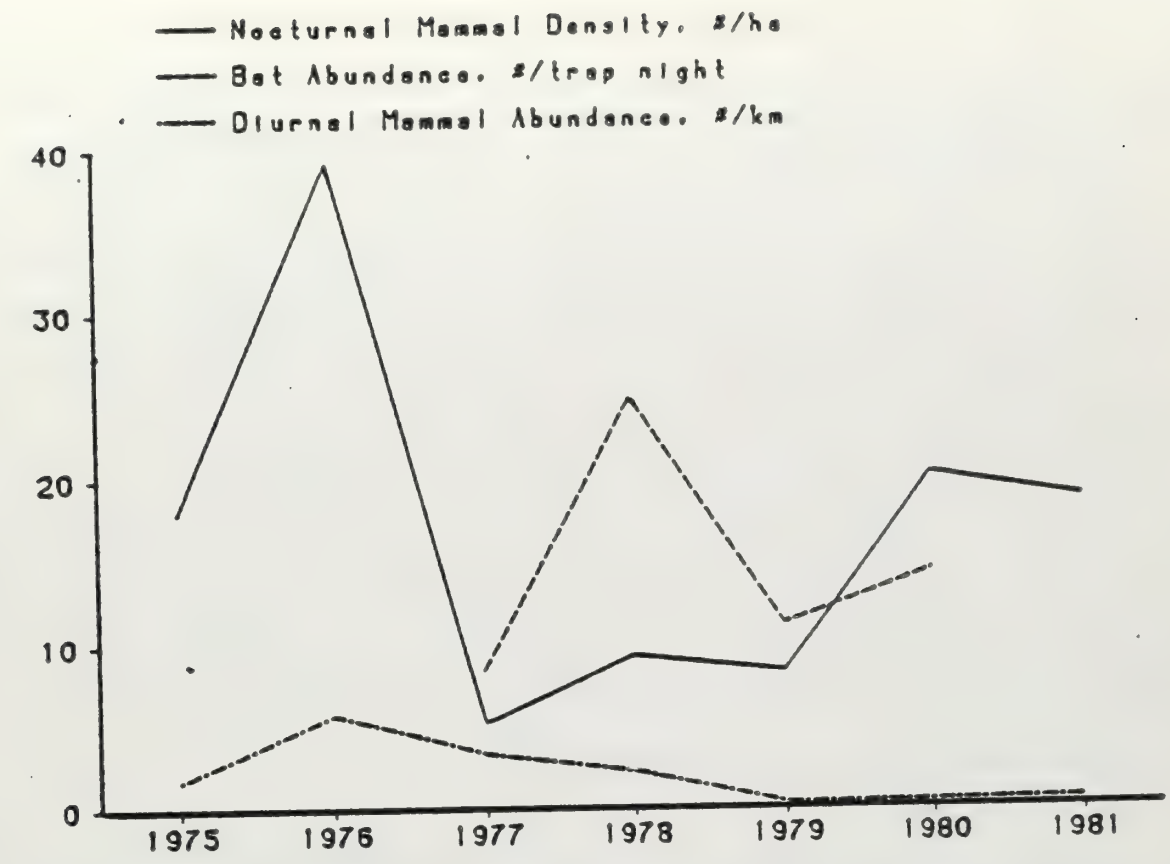

Fig. 4.4-18 Annual changes in abundance of nocturnal mammals, diurnal mammals, and bats, 1975-1981.

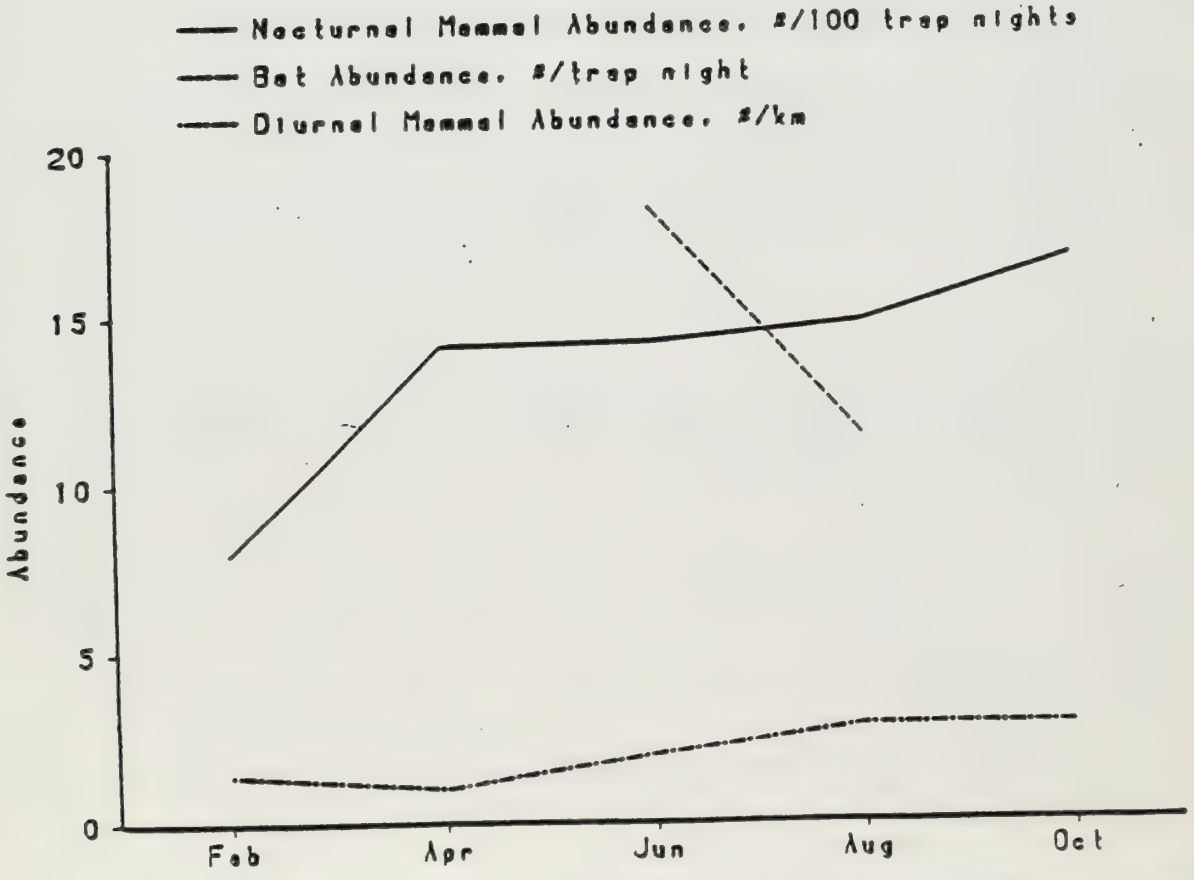

Fig. 4.4-19 Seasonal changes in abundance of nocturnal mammals, diurnal mammals and bats, February-October.

B. Changes Over Seasons Mammals active through all seasons showed a definite decrease in abundance in February (winter), but showed little change between the other seasons (Fig. 4.4-19). Rodent activity was lowest in February, increased significantly ($p<0.01$) in April, then changed only slightly through October (Table 4.4-21). Diurnal mammals were also at their lowest abundance in February and in April, then increased significantly ($p<0.05$) from June through October (Table 4.4-22). Richness and diversity of diurnal mammals peaked in June. Seasonal abundance for bats showed a different pattern. Bats peaked in June and declined significantly ($p<0.01$) in August (Table 4.4-23). Bat richness and diversity also peaked in June.

Table 4.4-21. Seasonal abundance, species richness and species diversity of rodents through seven years. Comparisons below each column show significant difference ($p \leq 0.05$) between seasons.

	RODENTS		
MONTHS	ABUNDANCE (Ind/100 Trap Nights)	RICHNESS (No. of Spp)	DIVERSITY (H')
February (F)	7.9±2.1*	2.6±0.4	0.51±0.14
April (A)	14.1±2.3	3.2±0.3	0.75±0.10
June (J)	14.2±1.4	4.4±0.4	0.97±0.10
August (Au)	14.8±1.5	4.7±0.3	1.01±0.09
October (O)	16.7±2.0	3.7±0.4	0.76±0.09
	F < A,J,Au,O	F < A,J,Au,O A,O < J,Au	F < A,J,Au,O A,O < J,Au

*Standard Error of the Mean

Table 4.4-22. Seasonal abundance, biomass, species richness and species diversity of diurnal mammals through seven years. Comparisons below each column show significant differences ($p \leq 0.05$) between seasons.

	DIURNAL MAMMALS			
MONTHS	ABUNDANCE (No/km)	BIOMASS (Kg/km)	RICHNESS (No. of Spp)	DIVERSITY (H')
February (F)	1.4±0.4*	9.6±3.2	1.8±0.2	0.23±0.06
April (A)	1.0±0.3	9.3±3.5	1.9±0.2	0.26±0.06
June (J)	2.0±0.4	8.0±2.1	2.4±0.3	0.36±0.08
August (Au)	2.8±0.7	16.2±4.5	2.1±0.2	0.31±0.07
October (O)	2.8±0.9	24.8±12.2	1.9±0.3	0.22±0.06
	F,A < J,Au,O J < Au,O	F,A,J < O	F < J	F < J

*Standard Error of the Mean.

Table 4.4-23. Seasonal abundance, biomass, species richness and species diversity of bats through four years. Comparisons below each column show significant differences ($p \leq 0.05$) between seasons.

	BATS			
MONTHS	ABUNDANCE (Ind/Trap Night)	BIOMASS (Kg/Trap Night)	RICHNESS (No. of Spp)	DIVERSITY (H')
June (J)	18.2±2.5*	0.28±0.04	4.7±0.4	1.19±0.09
August (Au)	11.4±2.0	0.13±0.03	3.3±0.3	0.91±0.10
	Au<J	Au<J	Au<J	Au<J

*Standard Error of the Mean

C. Difference Among Habitats Rodent density was highest in the shrub habitats (Greasewood and Shadscale) and lowest in the two wooded communities (Juniper and Riparian; Table 4.4-24). Biomass was highest in the shrub habitats and Juniper whereas Riparian supported the lowest biomass of rodents. Although Riparian has the most diverse and productive vegetation on the tracts, it supported the lowest species richness and species diversity of rodents. Juniper, which has a very sparse ground cover, supported the richest and most diverse community of rodents.

Diurnal mammals were concentrated in Greasewood and Riparian habitats (Table 4.4-25). Biomass, richness and diversity were also highest in Riparian, whereas Greasewood supported the lowest biomass, richness and diversity. Low values for these parameters in Greasewood, as well as in Shadscale and Juniper, were due to the dominance of the

Table 4.4-24. Abundance, biomass, species richness, and species diversity of rodents in four vegetation types through seven years. Comparisons below each column show significant differences ($p \leq 0.05$) between habitats.

	RODENTS			
HABITAT	DENSITY (Ind/ha)	BIOMASS (Kg)	RICHNESS (No. of Spp)	DIVERSITY (H')
Greasewood (G)	21.2±4.4*	2.3±0.4	5.0±0.6	1.14±0.13
Shadscale (S)	19.4±5.6	1.9±0.6	4.4±0.6	1.15±0.09
Juniper (J)	12.6±3.9	1.9±0.7	6.4±0.8	1.53±0.12
Riparian (R)	14.5±4.0	1.0±0.2	3.8±0.6	0.65±0.13
	J,R < G,S	R < G,S,J	G,S,R < J R < G	G,S,R, < J R < G,S

*Standard Error of the Mean

Table 4.4-25. Abundance, biomass, species richness and species diversity of diurnal mammals in four vegetation types through seven years. Comparisons below each column show significant differences ($p<0.05$) between habitats.

	DIURNAL MAMMALS			
HABITAT	ABUNDANCE (No/km)	BIOMASS (Kg)	RICHNESS (No. of Spp)	DIVERSITY (H')
Greasewood (G)	2.6±0.6	4.4±1.8	1.7±0.2	0.19±0.05
Shadscale (S)	1.3±0.3	7.5±2.6	1.7±0.2	0.19±0.04
Juniper (J)	1.5±0.3	5.4±1.7	1.9±0.2	0.28±0.07
Riparian (R)	2.6±0.6	35.5±8.6	2.8±0.3	0.46±0.07
	S,J < G,R	G,S,J < R	G,S,J < R	G,S,J < R

*Standard Error of the Mean

cottontails in drier upland habitats. In Riparian, other diurnal mammals, such as mule deer (Odocoileus hemionus), beaver (Castor canadensis) and porcupine (Erethrizon dorsatum), concentrated along the White River resulting in a richer, more diverse mammalian fauna.

When livestock abundance was included with the diurnal mammals, no habitat differences were distinguishable. Inclusion of livestock did not alter richness or diversity relationships between habitats. Biomass, however, increased significantly in Shadscale (684 kg/km with livestock; 7.5 kg/km without livestock). Even with livestock included, Riparian continued to support the highest biomass (1456 kg/km with livestock; 35.5 kg/km without livestock).

Since bat sampling was limited to one site, no quantitative information on distribution was available. Based on our casual observations and published data (Barbour and Davis 1969), bat species found on the

tracts roost in trees, caves, and rock crevices. These habitat types are scarce east of Evacuation Creek, suggesting that bats should occur at low densities in this area. Areas of high densities are probably Riparian habitat and the western portion of the tracts, specifically Tract Ua.

D. Changes Among Species The abundance and habitat distribution of some individual mammal species provide some insight into the annual, seasonal and habitat differences in the mammal community.

Of thirteen species of rodents live-trapped through seven years some species dominated numerically. White-tailed antelope squirrels (Ammospermophilus leucurus), diurnally active rodents, were at measurable density in the shrub communities in 1975 and 1976 (5 ± 2 ind per ha in Greasewood and 6 ± 0.5 ind per ha in Shadscale). During the drought of 1977, they became extinct in Shadscale and we had only occasional captures and opportunistic observations in Greasewood. In 1981, one individual was captured in Shadscale and one in Greasewood.

Ord's kangaroo rats (Dipodomys ordii), one of two granivorous mammals on the tracts, maintained a near constant density in the two shrub communities over five years, 1975 through 1979, with a higher density in Greasewood than in Shadscale ($p\leq0.05$) (Fig. 4.4-20). In 1980 and 1981 densities increased significantly ($p\leq0.05$) in both shrub communities and kangaroo rats became consistent yet uncommon residents in the wooded communities. The kangaroo rats were the prime contributors to the 1980 and 1981 increase in rodent density (Fig. 4.4-18).

The other granivore, the small Apache pocket mouse (Perognathus apache), has had a steadily declining density in Greasewood, 7.0 ind/ha in 1975 and 1.5 ind/ha in 1981, averaging 3.2 ± 2.4 ind/ha through seven

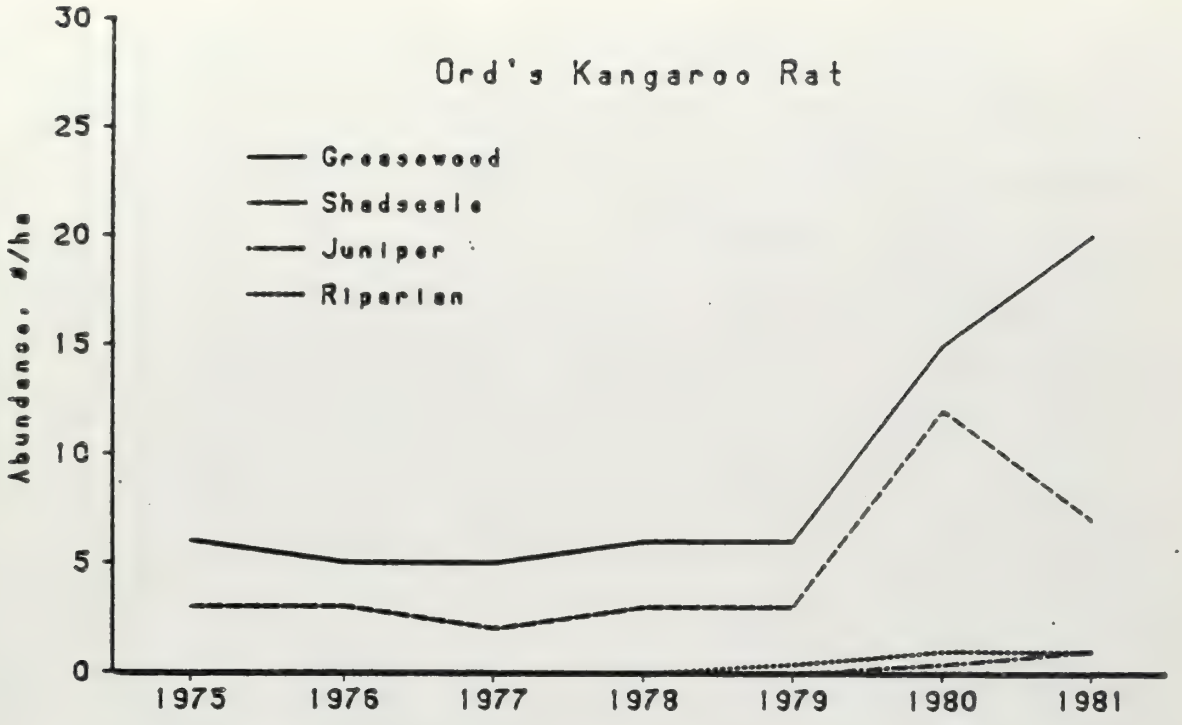

Fig. 4.4-20. Ord's kangaroo rat (*Dipodomys ordii*) density in four habitats through seven years.

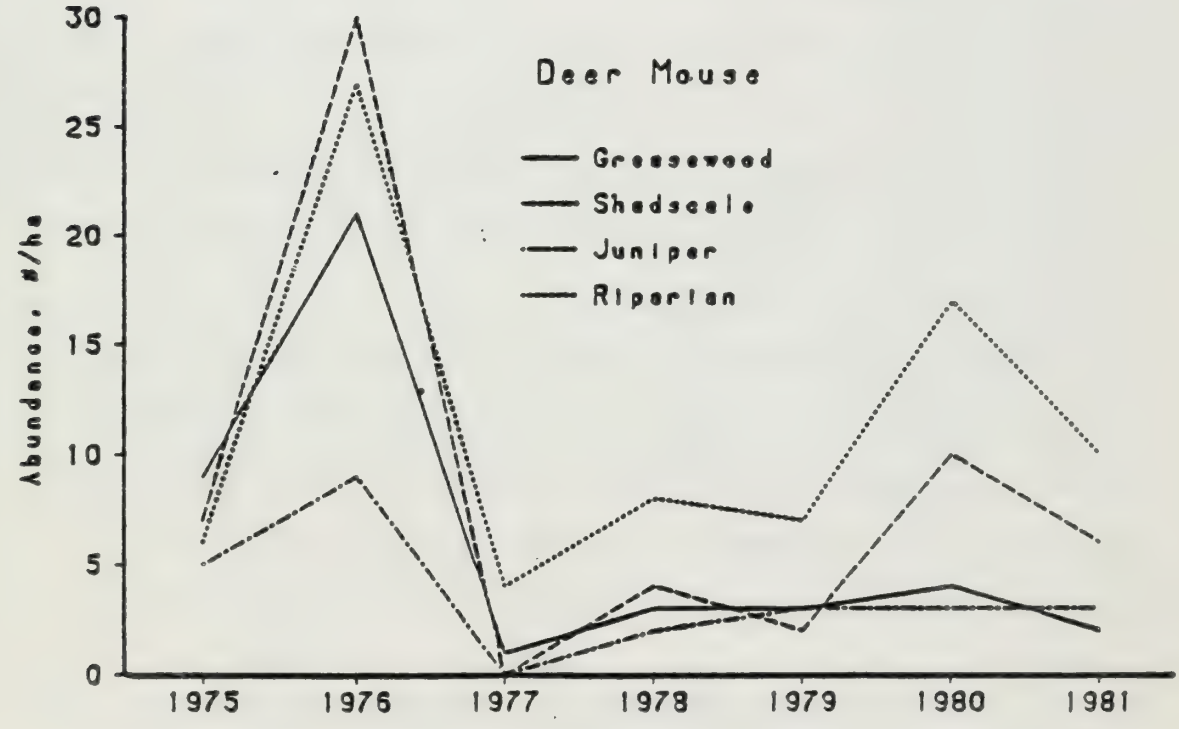

Fig. 4.4-21. Deer mouse (*Peromyscus maniculatus*) density in four habitats through seven years.

years. In Shadscale, densities were nearly constant from 1975 through 1980, 2.4±0.4 ind/ha, then increased to 7.4 ind/ha in 1981. In Juniper, densities were consistently low, 1.4±1.0 ind/ha, and only one pocket mouse was captured in Riparian.

Deer mice were the prime contributors to the high density of rodents in 1976 and the marked decline in 1977. The Riparian habitat was the only area which supported a relatively high deer mouse population in 1977 (Fig. 4.4-21). Although a few mice were captured during transect trapping in 1977, none were captured in grids in Shadscale and Juniper and only three were captured on the Greasewood grid.

Desert woodrats (Neotoma lepida) were found primarily in Juniper. The presence of desert woodrats in the shrub communities in 1975 and 1976, apparently due to increased productivity, was short-lived with extinction in Shadscale by 1977 and in Greasewood by 1978 (Fig.4.4-22). Desert woodrats were wanderers in Riparian, captured only once in 1974 and once in 1980. Riparian was the preferred habitat of the larger bushy-tailed woodrat (Neotoma cinerea). The bushy-tailed woodrat invaded the Juniper community in 1976, attaining a density of 3 ind/ha but since that time captures have been sporadic.

Among the diurnal mammals one species, the desert cottontail, was dominant. Cottontails were common to abundant from 1975 to 1978 but infrequently encountered since 1979. Although Greasewood supported the highest cottontail abundance through 1978, abundance did not differ significantly among habitats through seven years (three-way ANOVA, $p<0.05$). The cottontail's importance as prey for carnivores was suggested by a correlation between cottontail abundance and annual

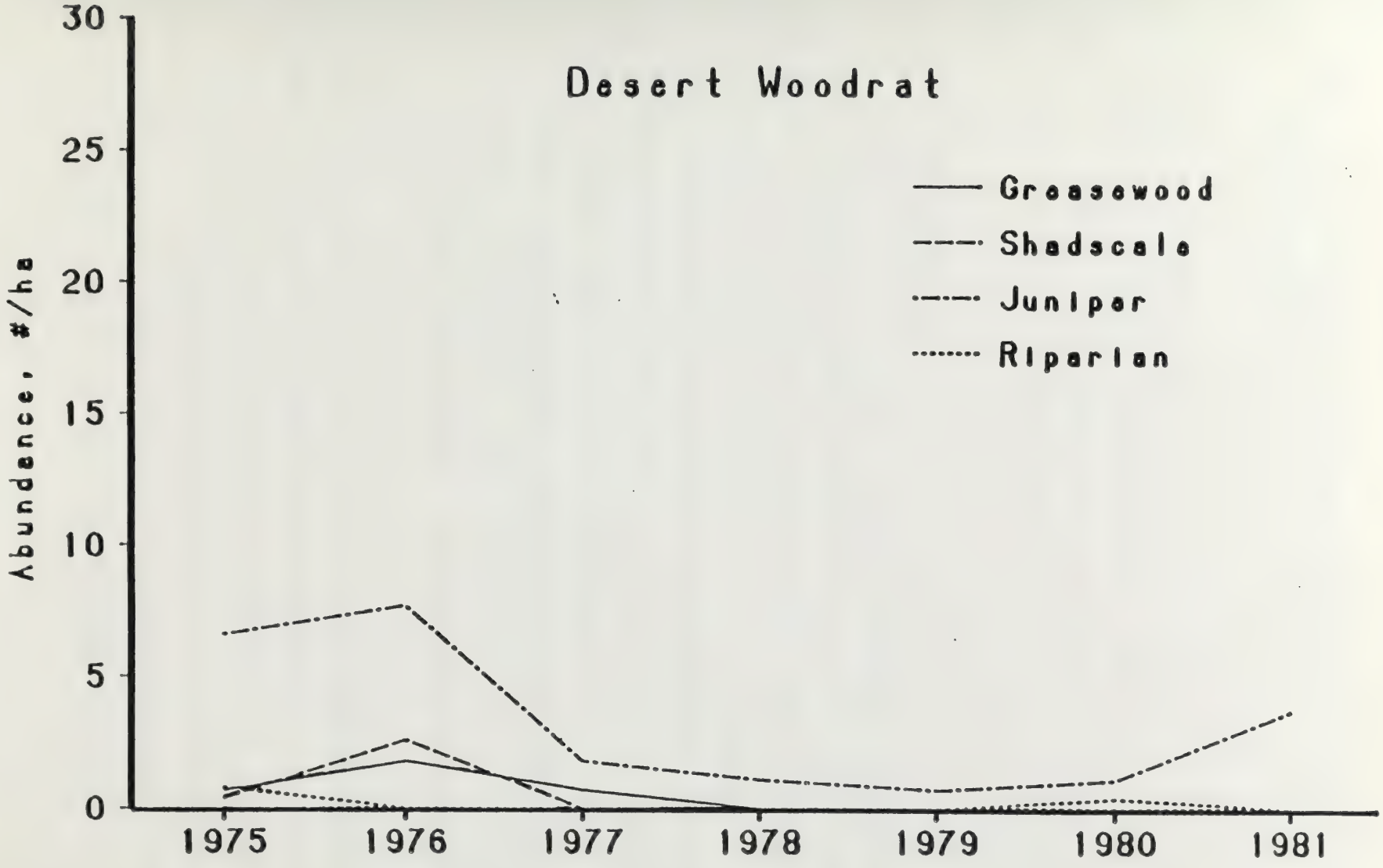

Fig. 4.4-22. Desert woodrat (*Neotoma lepida*) density in four habitats through seven years.

abundance of red-tailed hawks (Buteo jamaicensis) ($r=0.88$, $p<0.01$). Cottontail abundance, however, showed no correlation to the abundance of other raptors.

Several mammals were recorded on the tracts at such low abundance that documentation of changes between years was not possible. The most frequently reported carnivores were coyote (Canis latrans), badger (Taxidea taxus), and striped skunk (Mephitis mephitis). The latter was the only carnivore observed on transects.

The only ungulate which occurred regularly on the tracts was the mule deer (Odocoileus hemionus). Twenty-five to 50 individuals occur on and near the tracts. Their preferred habitat during the summer was Riparian and the adjacent Shadscale along the White River. During winter the deer concentrated in two areas - Shadscale-covered slopes adjacent to Evacuation Creek and Shadscale extending from the northern escarpment of the White River Canyon south of Bonanza, Utah, down to the White River. These areas have a southern aspect and are usually free of heavy snow cover. Pronghorn (Antilocapra americana) are found north of the White River. The only time they entered the tract's boundaries was during the drought, 1977, when they were observed along the river's northern banks.

4.4.7.4 Literature Cited

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4.4.8 Special Studies

During the course of monitoring terrestrial fauna on Tracts Ua and Ub, the techniques of sampling and analysis of vertebrates are constantly evaluated. During 1981, three analyses were carried out to determine if currently used techniques were the most efficient. These analyses were of: (1) the adequacy of reduced transect sampling and of bird abundance calculations; (2) the adequacy of reduced trapping of rodents; and (3) grid trapping of rodents in October versus August.

4.4.8.1 Adequacy of Reduced Transect Sampling and Abundance Estimates

A. Methods - To determine the adequacy of sampling vertebrate populations with fewer days, community characteristics (abundance, diversity, richness, evenness and dominance) were calculated from three subsets of the data: (1) days one and two; (2) days one, two and three; and (3) days one, two, three and four. Correlations were developed between these characteristics and those obtained from the full five-day sampling sessions. These analyses were carried out for morning and evening transects which sampled both birds and mammals, and for mid-day

transects which sampled reptiles. Because periods of bad weather lasting more than 24 hours might affect the variability of shorter sampling periods, data from days one, two and three were compared with data from days one, three and five.

To calculate densities of birds, an estimator based on the Fourier Series was used. Total community density estimates thus obtained were compared with abundance estimates obtained from the data expressed simply as bird seen per kilometer.

B. Results In general, correlation coefficients showed that abundance, richness and diversity could be estimated by reduced sampling sessions (Table 4.4-26). Correlation coefficients for these characteristics were above 0.90 for two-day sampling sessions of morning transects and four-day sampling sessions of both evening and mid-day transects. Correlations for evenness and Simpson's Index were not as high as those for abundance, richness and diversity. However, evenness and Simpson's Index are generally not as important in analyzing changes in communities.

Data from the three types of transects were pooled to compare estimates from the first three-day period of each sample session with those made from days one, three and five. Correlation coefficients did not show an advantage in sampling on days one, three and five.

Total bird-density estimates obtained from the Fourier Series Estimator were closely correlated with abundance measures expressed in numbers per kilometer ($r=.93$, $n=136$ for all months and habitats combined). Correlations were also run separately for each month and habitat. Correlations were highest in June ($r=.98$) and February ($r=.99$).

Table 4.4-26. Correlation coefficients (r) between reduced sampling sessions and five-day sessions. Sample size is 253 for A.M. transects, 247 for P.M. transects, and 113 for reptile transects.

Abundance	Birds and Mammals						Reptiles		
	A.M. Transects No. of Days			P.M. Transects No. of Days			Mid-day Transects No. of Days		
	4	3	2	4	3	2	4	3	2
Abundance	.99	.97	.92	.99	.91	.82	.99	.97	.95
Diversity	.98	.95	.90	.95	.84	.72	.96	.88	.79
Richness	.99	.97	.95	.95	.88	.81	.97	.89	.80
Evenness	.85	.67	.57	.89	.81	.71	.91	.88	.65
Simpson's Index	.88	.69	.57	.89	.82	.75	.94	.86	.65

Correlation coefficients for each habitat taken separately showed the best predictions of density from abundance occurred in Greasewood and Riparian (r=.90 for both).

The two methods of analyzing data (density estimates and abundance measures) were also compared in terms of three-way Analysis of Variance (ANOVA). The significance levels for each effect in the ANOVA model showed little difference between the two techniques in terms of detecting differences among years, months and habitats. However, in comparison between individual species, density estimates are needed.

4.4.8.2 Adequacy of Reduced Trapping

A. Methods - Correlations were calculated between four simpler trapping techniques and the large 12 x 12 grids of 144 Sherman live traps. The simpler techniques were (a) 5 x 5, 15 m apart, (b) 1 x 25,

40 m apart, (c) 1 x 25, 15 m apart, and (d) 1 x 12, 15 m apart, 2 traps at each station. One or two of these simpler techniques were run concurrently with 12 x 12 grids. Also, correlations were calculated between 12 x 12 grids and subsets of the 12 x 12 grids (11 x 11, 10 x 10, ... 5 x 5). The number of trapping nights needed was analyzed by calculating correlations between population estimates obtained after 5 days and estimates obtained after 4, 3 and 2 days of trapping.

B. Results Correlations between simple trapping regimes and 12 x 12 grids trapped concurrently were generally low (Table 4.4-27). Of the five parameters, diversity was predicted by simple regimes with the most accuracy, but abundance and richness, parameters of prime importance, were not closely correlated to the reference grids.

Correlation coefficients between 12 x 12 grids and subsets of the data quickly decreased as grid size was reduce. Abundance estimates were fairly reliable using grid size down to 7 x 7 ($r^2>0.90$) but the accurance of diversity and richness was much reduced with a 9 x 9 grid ($r^2=0.87$ for both).

Correlations made with parameters calculated from data reduced temporally (Table 4.4-28) showed that abundance estimates could be reliably obtained from only 3 nights of trapping. However, diversity, richness and evenness estimates were inadequate-based on data from three trapping nights.

In general, the results indicate that small-mammal community characteristics cannot be adequately determined by a reduced sampling effort. Reducing the number of nights of trapping produced reliable estimates of some parameters but simple sampling regimes and smaller grids do not.

Table 4.4-27. Correlation between simple trapping regimes and 12x12 grids for 5 community parameters.

	Trap Regime (meters between traps)			
	5x5 (15)	1x25 (40)	1x25 (15)	1x12 (15)
n=	12	4	16	16
Abundance	.66*	.27	.61*	.30
Diversity	.85**	.75	.80**	.61*
Richness	.66	.77	.69**	.26
Evenness	.24	.35	.46	.57*
Simpson's Index	.85**	.66	.60*	.55*

* $p<0.05$
** $p<0.01$

Table 4.4-28. Correlation coefficients (r) between reduced sampling time and 5 days of sampling as a reference. For each correlation n=15.

	Number of nights trapped		
	4	3	2
Abundance	.99**	.99**	.95**
Diversity	.97**	.92**	.74**
Richness	.89**	.74**	.44
Evenness	.51	.45	.47
Simpson's Index	.98**	.96**	.86**

** $p<0.01$

4.4.8.3 Comparison of August and October Grid Trapping

Initial plans for monitoring small nocturnal mammals on Ua and Ub considered August as the prime period for estimating small mammal trapping. Long-term trapping over seasons suggested that rodent abundance peaked in October. In order to determine if October was indeed the peak of rodent density, large trap grids (144 live traps in a 12 x 12 array) were conducted in both August and October at eight locations in 1981.

Results

Mean density (over eight locations) in October was equivalent to that in August (Table 4.4-29). Standard deviations suggest that there were slightly more differences among habitats in August than in October. Biomass decreased slightly in October due to fewer captures of large rodents, i.e., woodrats and kanagroo rats. Species richness declined significantly in October ($t=2.12$, $df=7$, $p<0.10$). Diversity also declined but not significantly.

Table 4.4-29. Differences between community characteristics from August and October trapping of small nocturnal mammals.

	Density (ind/ha)	Biomass (kg/ha)	Richness (no/spp)	Diversity (H')
August	19.6±9.5	.80±1.1	6.4±1.5	1.33±0.39
October	19.6±7.6	.73±.33	5.1±1.4	1.15±0.36

The major loss of species between August and October occurred in Shadscale where the white-tailed antelope squirrel, desert woodrat, and bushytailed woodrat were not captured in October. The latter woodrat was

also absent in Greasewood in October with the Apache packet mouse absent in Juniper and the least chipmunk (Eutamias minumus) absent in Riparian.

Of the ten species capture in August, six declined in density in October, three increased, one remained stable, and one species, the montane vole, was captured for the first time in seven years. Changes in densities of two species were significant ($p<0.01$): deer mice increased 44% in density by October while Apache pocket mice declined 71%.

Because of thse results, especially the reduction in species richness and change in relative species composition, the August sampling session will be retained in the wildlife monitoring program.

AQUATIC BIOLOGY

4.5 AQUATIC BIOLOGY

During the summer of 1981, the WRSP aquatic biology program, which was discontinued during the interim monitoring period (1977-1980), was redesigned and reinstituted. The monitoring program attempts to describe the aquatic ecosystem near the tracts in a manner which will allow the impacts of development to be identified and understood. The WRSP aquatic biology program is under the direction of Ecosystem Research Institute, Inc. of Logan, Utah.

This section discusses primarily the results of monitoring within the White River and Evacuation Creek near the tracts. Particular emphasis is given to the White River based upon its critical position relative to the WRSP and other probable Uinta Basin developments. A secondary, but interesting, aspect of the 1981 program also involved contribution by WRSP to the U.S. Fish and Wildlife Service study of endangered fish species in the Upper Colorado River Basin. Of particular note was the location of a large concentration of Colorado squawfish in breeding condition in the Yampa River. Given the concern about anthropogenic impacts upon these fishes' habitat, a section (4.5.5) of this report discusses the results of this special study.

4.5.1 Objectives

In developing and implementing the WRSP aquatic biology program, it has been recognized that the White River system adjacent to Tracts Ua and Ub is but a small segment of a much larger stream continuum. This under-

standing is important in identifying changes within the river biocenosis which are the result of upstream influences outside the control of the WRSP.

Sampling sites and monitoring parameters were selected based upon their ability to efficiently depict the structures and functions occurring in the stream ecosystem. Their selection also recognized that natural systems have a high degree of variability and that the biota exists within constraints set by the physical environment. In the development of this program, recognition was made of ecosystem theory. That is, producers, consumers, and decomposers constitute the biota which are regulated by the physical environment and their own interactions. These interactions constitute a series of interrelationships which can be quantified and allow not only the detection of change, but identification of the pathway of cause and effect leading to and resulting from the change. These relationships will be used in addition to the more conventional statistical comparisons of "state variables" to strengthen the ability of the program to quantify change.

The objectives of the 1981 Aquatic Monitoring Program are fivefold:

1. Characterize the White River and Evacuation Creek habitats in order to develop the most appropriate sampling sites for long-term monitoring.
2. Gather ecosystem-level data which would be important in tracing the fate and consequences of introduced foreign substances.
3. Develop appropriate techniques which can be utilized efficiently in a long-term monitoring program.

4. Determine those ecosystem parameters which have the greatest importance for long-term monitoring and the assessment of impacts.
5. Develop statistically significant interrelationships between aquatic and other ecosystems.

Objective (1), the selection of sample sites (see Figure 4.5-1), was addressed during an initial field investigation during April, 1981. Twenty-nine cross-stream transects were surveyed on the White River and nine on Evacuation Creek. The subsequent statistical analysis led to final site selection. The remaining objectives were addressed during monthly field investigations from May through December.

A second major portion of the 1981 Aquatic Program was to conduct a detailed study simultaneously with the U.S. Fish and Wildlife Service. The specific purpose of the WRSP investigation was to expand the information available on the physical, chemical, and biological habitat characteristics of the total upper trophic levels of the White River ecosystem. The objectives were:

1. Determine the food habits of the fish species located in the White River system.
2. Determine the distribution and relative densities of White River fishes.
3. Determine physical habitat preferences of the White River fishes.
4. Determine the biomass and composition of the lower trohic levels in the White River (periphyton, bethos, and drift) and their availability to White River fish.

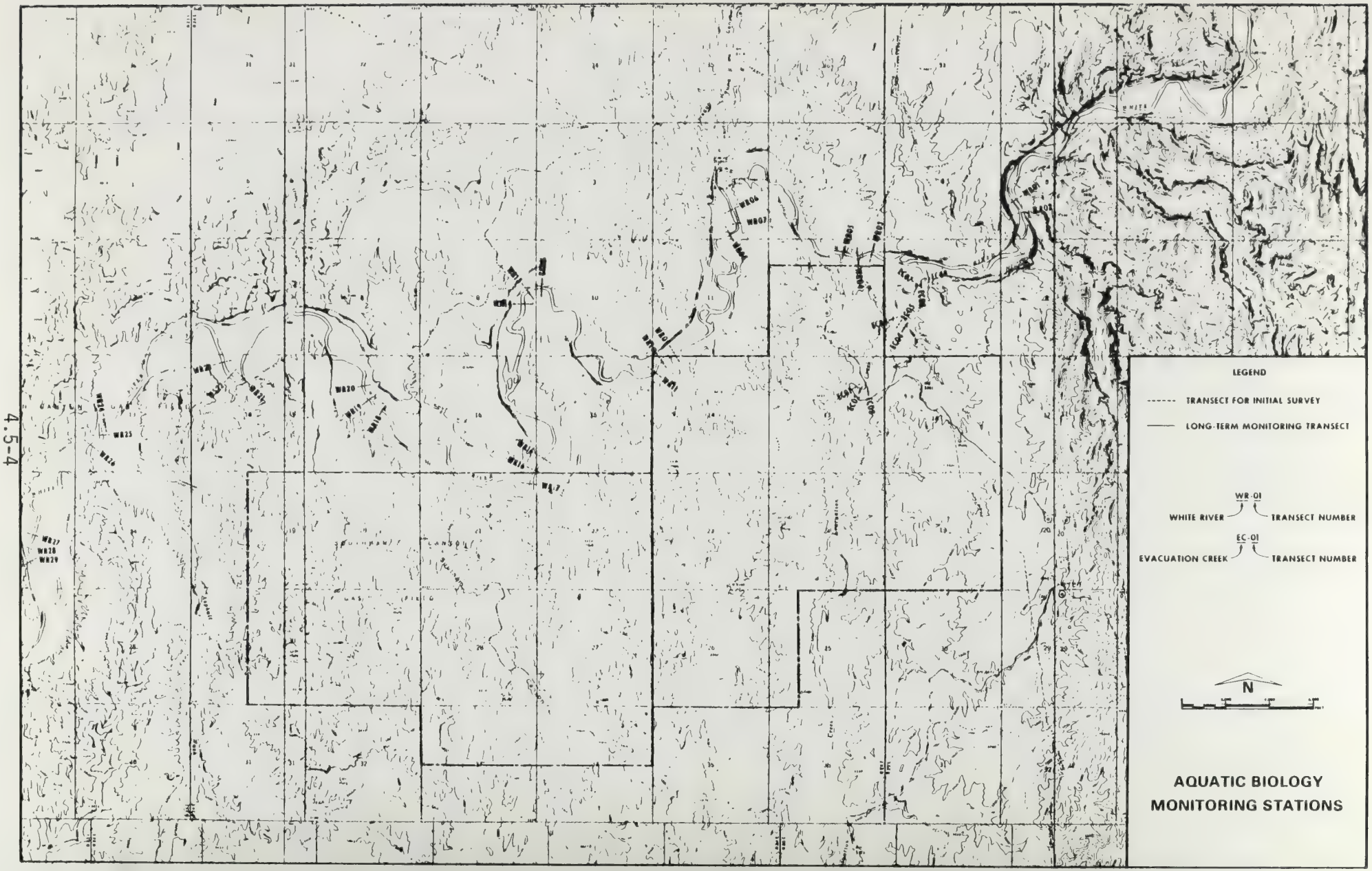
LEGEND
TRANSECT FOR INITIAL SURVEY
LONG-TERM MONITORING TRANSECT
WR-01
WHITE RIVER
TRANSECT NUMBER
EC-01
EVACUATION CREEK
TRANSECT NUMBER
N
AQUATIC BIOLOGY
MONITORING STATIONS

Figure 4.5-1

The purpose of this report is threefold: (1) To describe the White River continuum, (2) to present a description of the aquatic ecosystem of the White River and Evacuation Creek near Federal Lease Tracts Ua-Ub, and (3) to examine the usefulness of sites and parameters selected to identify change.

4.5.2 Methods

4.5.2.1 Physical Parameters

A. Field

a. Stream Cross-sections: During the initial stream survey, permanent benchmarks were established above the flood and a stream profile was surveyed at two-meter intervals from benchmark to benchmark. A Leitz 2B level, tripod, and metric stadia rod were used in the survey. In the stream, dominant substrate was recorded at two-meter intervals and classified according to the size classes listed in Table 4.5-1. At four-meter intervals, velocity at surface, bottom, and ten-cm depth intervals were recorded. During the initial stream survey, velocities were recorded at 30-cm intervals. At five equidistant locations on each river transect and three locations in Evacuation Creek, periphyton and interstitial sediment samples were collected using a 4.6 cm diameter plastic core tube Sediment samples were stored in labeled Ziploc bags and transported to the laboratory for size fractioning and organic content analysis of the smallest size fraction. These were coordinated with survey points and velocity readings to insure a complete data set. Velocities were determined in cm/sec, using a Marsh-McBirney current meter with two, six, and 20 second time constants.

Table 4.5-1 The substrate size classification used in the field to estimate the dominant substrate.

Size Class	Largest Dimension
BOulder	10 cm
CObble	5 - 10 cm
RUbble	1 - 5 cm
PEa Gravel	0.5 - 1.0 cm
SAnd	0.1 - 0.5 cm
SIlt	0.01 - 0.1 cm
CLay	0.01 cm and compacted

Table 4.5-2 The interstitial sediment size classfications used to determine the percent distribution of various sediment fractions.

#1	Size (mm)
1	12.7
2	4.0 - 12.7
3	0.5 - 4.0
4	0.25 - 0.50
5	0.25 (silt)

b. Light transmission was determined with depth using a one cm silicon blue photo cell (4 pi collector) embedded in an acrylic hemisphere with a white translucent covering. Light output was read on an ammeter with light transmission recorded as milli-or micro-amperes.

B. Laboratory Interstitial sediment samples are dried at 105°C for 24 hours and sieved with U.S.A. Standard Testing Sieves into five size fractions (see Table 4.5-2). The size fractions are weighed to the nearest 0.01 grams. The smallest size fractions were saved for organic content analysis.

4.5.2.2 Physical Parameters

A. Field One liter bottles were filled with water, frozen, and transported to the laboratory for analysis.

B. Laboratory One hundred twenty-five mls of water was filtered for analysis of nitrite, nitrate, total dissolved phosphorous, and orthophosphate. The filters were wrapped in foil and refrigerated for later chlorophyll analysis.

Reactive nitrite was measured by the diazotization method and reactive nitrate content was obtained using the cadmium-reduction method in Strickland and Parsons (1968). The ascorbic acid technique, also described in Strickland and Parsons (1968), was followed for reactive orthophosphate determination. Total phosphorous was measured as described in Standard Methods (1971). Ammonia concentration was measured by the indophenol method by Solorzano (1969). Total suspended matter was obtained following the procedure described in Standard Methods (1981).

Turbidity was measured using a Bausch and Lomb Spectronic 88 spectrophotometer with a one cm cell. Transmittance was read at wavelengths of 435, 630, 645, 660, and 750 nm after shaking the sample.

Chlorophyll was measured by the fluorometric and trichromatographic procedures in Standard Methods (1980).

4.5.2.3 Organic Parameters

A. Field Organic materials were collected from the White River with drift nets, benthic samples, and sediment samples.

Drift nets were set for approximately four-hour intervals. Floating debris collected, including invertebrates, in the drift nets was preserved in ten percent formalin and transported to the laboratory.

Benthic samples were taken at five equidistant locations along cross-stream transects in the river and three locations in Evacuation Creek with core tubes or a Hess Sampler. During a Hess sample, the river bottom was manually scraped for macroinvertebrates and organic debris present in the water column or on the bottom to an approximate maximum depth of ten cm. After collection, samples were preserved in ten percent formalin and transported to the laboratory. The procedures for sampling macroinvertebrates are discussed in more depth in the following invertebrates section.

Sediment core samples were collected corresponding with benthic and chlorophyll samples. A plastic core tube (4.6 cm dia) was used and the sample was stored in Ziploc bags and transported to the laboratory.

B. Laboratory Drift and invertebrate samples were floated in a sugar-water solution and poured through a U.S.A. Standard Testing Sieve (No. 60) to separate the organic and inorganic materials. Samples

greater than eight ounces weight were subsampled with a mechanical sampler. The organic material was then picked for insects and fishes. The remaining organic debris was dried at 105°C for 24 hours and weighed on a top-loading Sartorius Balance.

Substrate samples were dried at 105°C for 24 hours and sieved into five size fractions as described above. Approximately one ml of the silt fraction was redried in a crucible for 24 hours at 105°C, cooled in a dessicator to room temperature and weighed to the nearest 0.00001 g on an analytical balance. The sample was then burned in a preheated muffle furnace at 600°C for 20 minutes, cooled, and reweighed. The weight loss on ignition was calculated as total organic content.

4.5.2.4 Primary Producers

A. Field Rocks measuring at least 4.6 cm in diameter and exhibiting what was judged to be average algal coverage for each site were collected and frozen. Where rocks were not found, i.e., gravel, sand, silt, etc., 4.6 cm diameter clear, plexiglas tubes were used for collection of specimens.

B. Laboratory Rocks were thawed and a 4.6 cm diameter circle was scraped clean and suspended in 50 mls tap water and six drops of Lugol's solution. Clear tube periphyton samples were suspended in 50 mls of tap water, agitated, and allowed to settle until most large sediment particles settled out. The supernatant was decanted into a sample bottle to which six drops of Lugol's solution was added. Samples were then refrigerated in the dark until analysis. A blender was used to break calcareous and filamentous algae into countable units.

An automatic micropipette was used to withdraw a 50 microliter sample. The sample was placed on a glass slide with a cover slip. There was minute leakeage around the cover slip but the advantage gained in being able to use a higher power objective was felt to make up for this possiblity of error in count. Identification to lowest practical taxon was made and recorded for 50 to 110 fields of view per sample. Where filamentous forms prohibited this method, a Sedgwick Rafter counting cell was used at a lower power magnification.

Materials included Zeiss phase microscope, glass slides, cover slips, Sedgwick Rafter counting chamber, 50 lambda Eppendorf automatic pipette, five ml graduated pipette, and Lugol's solution.

4.5.2.5. Invertebrates

A. Field Benthic macroinvertebrates were sampled along each transect at the above specified intervals across the river. These corresponded to chlorophyll (periphyton) and interstitial sediment sampling sites. Wherever possible, a Hess Sampler was used, sampling 1320 cm^2 of bottom with a net mesh size of 0.3 mm. Occasionally, deep water and/or slow current restricted use of the Hess Sampler. At these sites, sediment core samples were taken using a plastic core tube. Two sizes of tubes were used at different times, one sampling an area of 88.2 cm^2 and the other an area of 16.6 cm^2. Generally, when employing the smaller tube, three cores were taken at each site for a total area of 49.8 cm^2.

Insects floating in the water column were sampled using drift nets of two sizes (27.5 cm diameter with a 1.0 mm mesh size and 30.5 cm x 45.7

cm with a 0.5 mm mesh size) which were anchored to the river bottom and set in the water column at each transect during the time in which other samples were collected. Starting in July, drift samples were taken over 24 hour period at a site below the Ignatio Bridge, and sampling of drift at each transect was discontinued. These nets were emptied at five or six regular intervals over a 24-hour sampling period.

All invertebrate samples were preserved in the field in ten percent formalin or 70 percent ethanol.

B. Laboratory Drift and benthic samples were floated in a sugar-water solution and poured through a U.S.A. Standard Testing Sieve (No. 60) to separate organic and inorganic portions. This process was repeated three times. Samples greater than eight ounces and those with very large numbers of insects were subsampled using a mechanical subsampler (Waters 1969). The remaining organic materials were manually picked to remove all invertebrates and fish which were preserved in 70 percent ethanol. All organisms were then identified to lowest practical taxon, counted, and measured to the nearest mm (except exoskeletons). The remaining debris was then dried at 105°C for 24 hours and weighed on a Sartorius balance.

In order to determine insect biomass, a total of 300 insects from three order (134 Trichoptera, 111 Diptera, and 55 Ephemeroptera) of one mm length increments were selected from samples taken on the White River. Each size group of each order was dried at 105°C for four hours and weighed to the nearest 0.01 mg on a Mettler analytical balance.

4.5.2.6 Production - Respiration

A. Field Periphyton productivity in the White River was measured using Production/Respiration Chambers (Figure 4.5-2). The chambers were made of 1/4" thick Lexan plastic. They were 29 cm X 29 cm and 19.7 cm deep. Water circulation through the chambers was accomplished with a Model 1-42 Little Giant submersible pump.

Substrate canisters had been previously anchored to the stream bottom at Transect 18 in Southam Canyon. The canisters were constructed of stainless steel tubing 14.7 cm inside diameter and 35 cm in depth. A basket made from perforated aluminum (3 mm holes) 14 cm in diameter and 20.5 cm deep was placed in each canister to hold the substrate which consisted of randomly selected rocks from the river bottom.

One P/R chamber was bolted directly to a substrate canister. The other chamber was placed directly next to it. Two or three rocks containing periphyton were selected from the river bottom and placed into the second chamber. The chambers were then filled with water, the lid sealed, and the chamber submersed in the river.

An oxygen probe was inserted through a hole in one side of each chamber. The probes were then connected to YSI Model 54 oxygen meters and the change in O_2 was recorded on an Esterline Angus recorder.

The chamber on the canister was equipped with two Asco solenoid valves that were, in turn, connected to a 24-hour Dayton time clock, Model 6 x 758. The solenoid valves were activated at six-hour intervals to flush the chamber when O_2 levels became too high. The second chamber had to be flushed out manually. Power for the recorder, submersible pumps, and time clock was supplied by a portable generator. The chambers

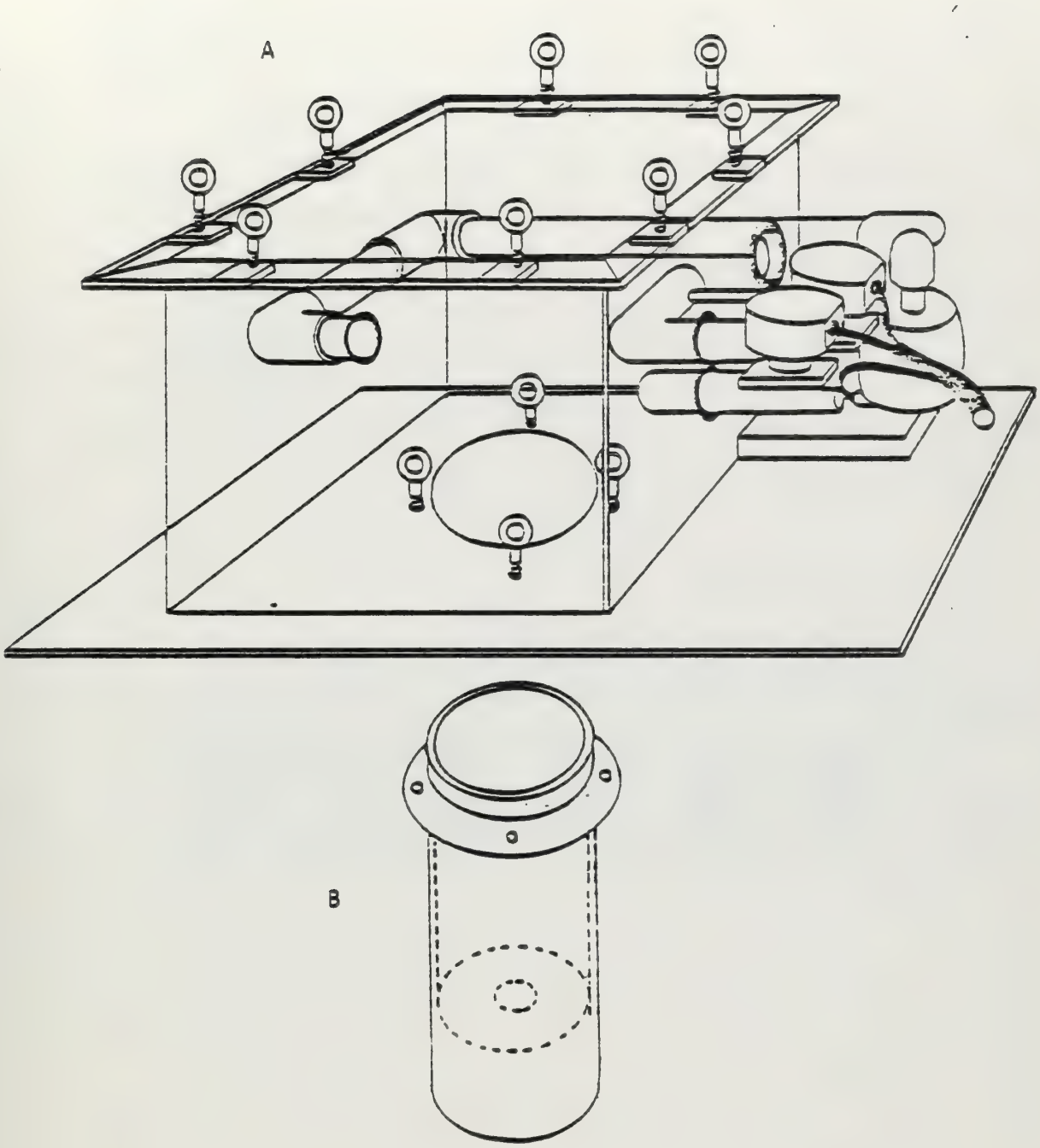

Figure 4.5-2 A - Production-Respiration chamber.
B - Substrate canister anchored to the stream bottom and bolted to the P/R chamber.

were run continuously for 72 to 96 hours. At the end of the monitoring period, the substrate from the chambers was put into Ziploc bags, refrigerated in the dark, and transported to the laboratory.

B. Laboratory In the laboratory, two 4.6 cm circles were scraped from the rocks in each chamber, one for the determination of chlorophyll a and one for the identification of periphyton. The remaining area of the rocks was scraped to determine the total mass of chlorophyll a in each chamber. The volume that was displaced by the rocks in each chamber was also measured so that dissolved oxygen levels could be standardized to the volume of water present.

4.5.2.7 Decomposition

A. Field Leaf packs were used to determine the rate of decomposition of leaves in the White River. Dry, fallen, cottonwood leaves from the surrounding area were taken to the laboratory and leached in distilled water for 24 hours. They were then dried in an oven at 105°C for 24 hours. The dried leaves were weighed into groups of approximately 4 g on a Sartorious balance. The actual weights were recorded and the leaves were bound together with a brass paper fastener. They were then placed into individual containers (Figure 4.5-3). The leaf pack containers were made from PVC pipe with an inside diameter of 6.5 cm and an overall length of 15 cm. One end was covered with 1/8" plexiglass and the other end of the container had either stainless steel mesh wire (3 mm opening) or Nitex netting with an opening of 0.7 mm.

The containers were placed in stainless steel racks in groups of six (Fig. 4.5-3). Each group contained three large mesh containers and three

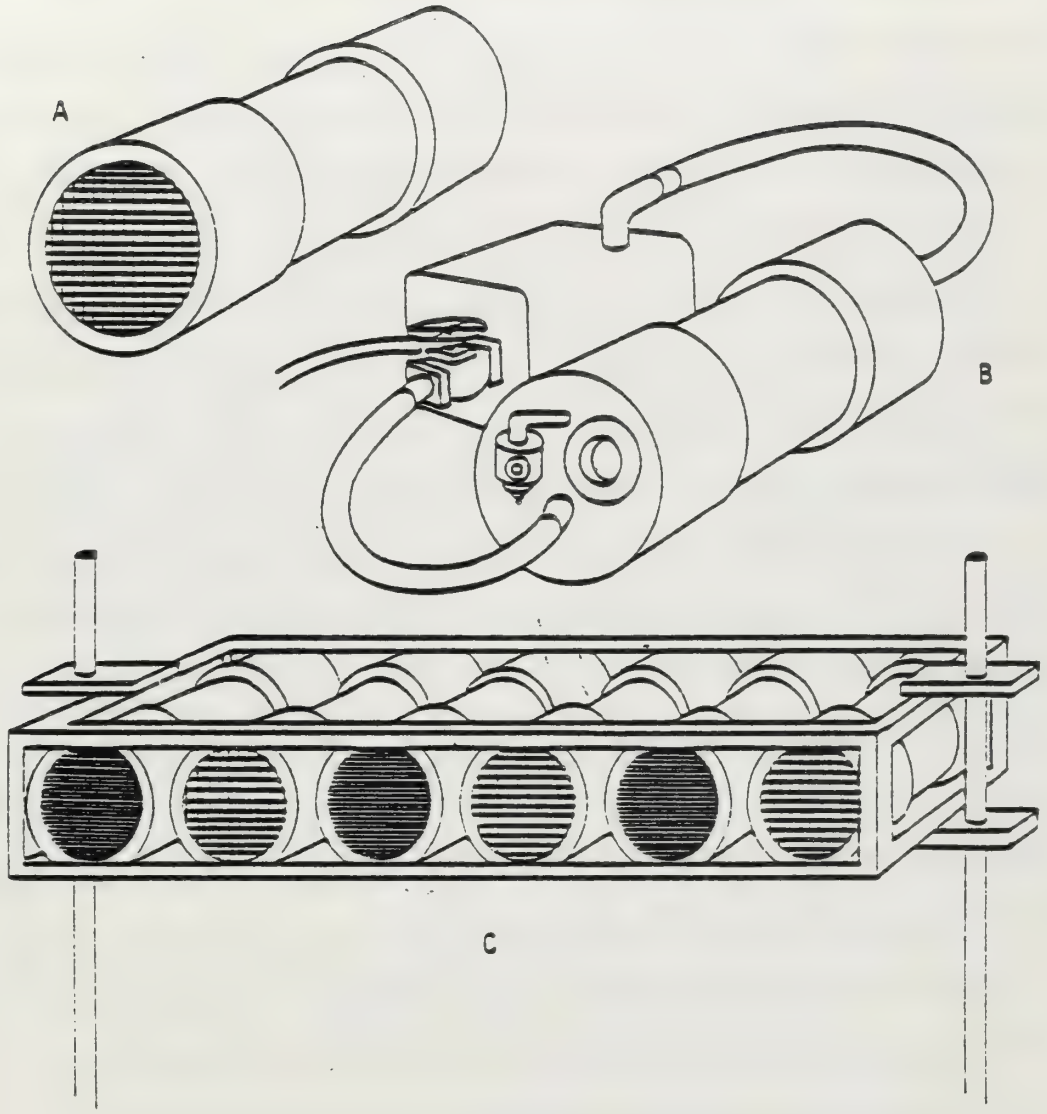

Figure 4.5-3 A - Individual leaf pack container.
B - Leaf respiration chamber.
C - Group of six leaf packs.

containers with the smaller mesh. To start, four six-group packs were anchored to the bottom of the river at Transect 18 in Southam Canyon. One group of six containers was to be removed from the river each month. Every other month, four new racks of containers were to be added and the decomposition rate monitored over a four-month period. This would give four repetitions and a total of 96 leaf packs over a one-year period.

When the containers were removed from the river, each pack of leaves was monitored for a period of 10-15 minutes to determine the respiration rate of organisms on the leaves. This was accomplished by taking the leaves from individual containers and placing them in a respiration chamber of approximately the same size as the leaf pack container (Figure 4.5-3). The respiration chamber was made from a piece of PVC pipe 6.5 cm inside diameter and approximately 15 cm long. On either end was a PVC cap with a piece of plastic tubing connected to a Model P-AAA Little Giant submersible pump for water circulation. A 1/4" NPT valve was placed in the line to control water flow. An oxygen probe was inserted into a hole in one of the PVC caps and connected to a YSI Model 43 oxygen meter to monitor the respiration rate.

The leaves were removed from the respiration chamber, placed in Ziploc bags, and refrigerated for transportation to the laboratory.

B. Laboratory In the laboratory the leaves were leached in distilled water for a period of 24 hours, oven dried at 105°C for an additional 24 hours, and weighed to determine the amount of weight loss.

4.5.3 White River Continuum

The relationship between the amount of autotrophic and heterotrophic activity in a stream system is expressed as the ratio of the rates of gross primary production to community respiration (P/R) (Odum, 1956). The River Continuum Hypothesis (Vannote et al., 1980) embodies the concept of ecological changes, such as P/R, as a function of drainage basin gradient from headwaters to river mouth. A basic element of the hypothesis is the dependence of downstream communities on upstream processes. It is the balance between primary production and respiration (P/R) and between the storage-processing and export, which constitute the basic features of the White River. It is the purpose of this discussion to describe the changes in the major physical, chemical, and biological properties of the White River along its 240 km-long gradient.

4.5.3.1 Physical Properties One of the important factors in determining sediment transport, substrate size, substrate stability, and consequent biological components is gradient (Hynes, 1970). In the White River, the longitudinal gradient decreases from 2.55 m/km at the headwaters to 0.53 m/km at the confluence with the Green River. An exception is at the site location for the proposed White River Dam as shown in Figure 4.5-4. The distribution of dominant river substrate sizes follows the above changes in gradient with larger substrates occurring in stretches of higher gradient.

4.5.3.2 Biological Properties There are two food sources for the consumers in any river system. These are allochthonous and autochthonous organics.

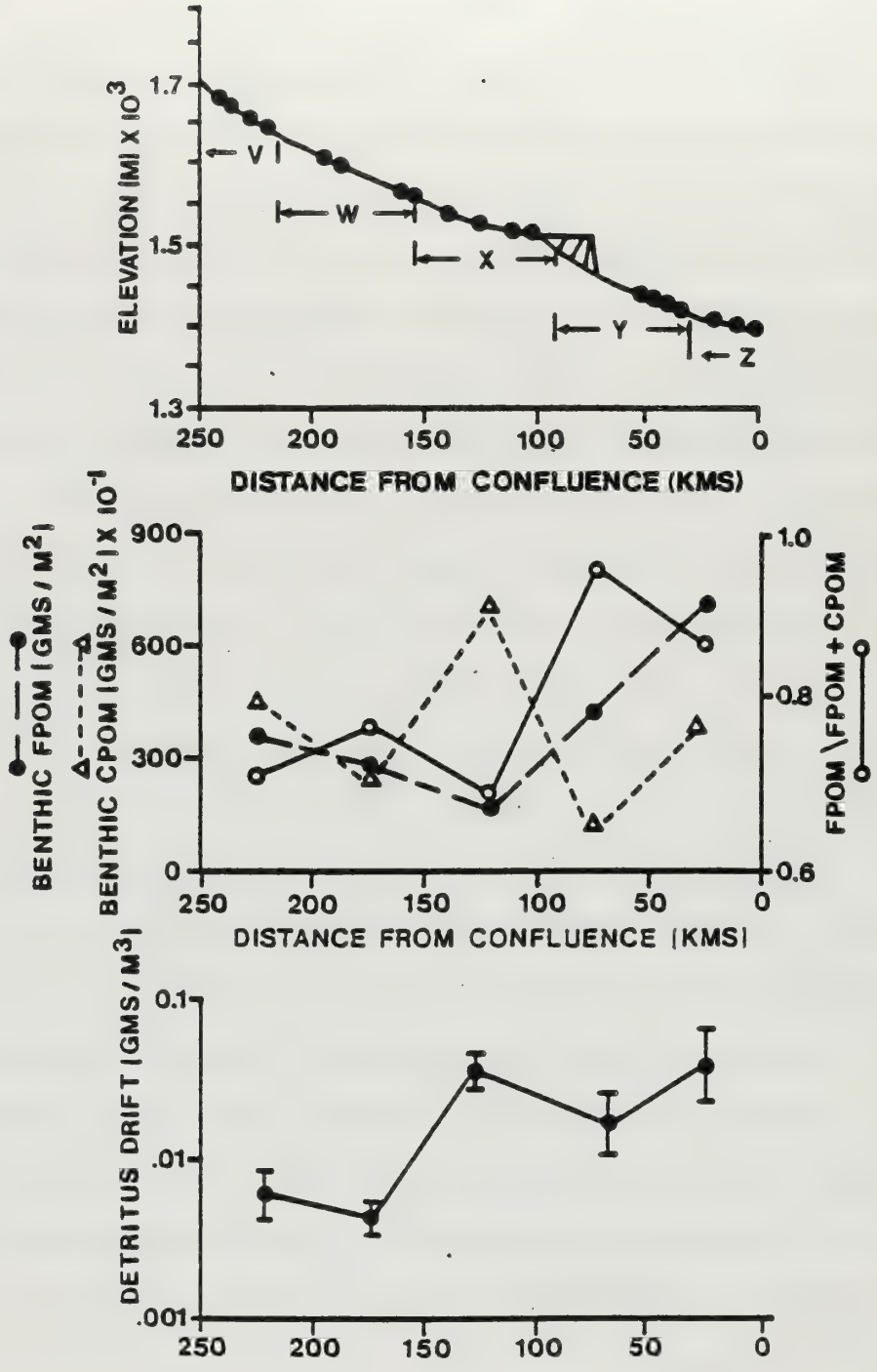

Figure 4.5-4 Distribution of river gradient, benthic organic matter, and drift detritus in the water column as a function of distance upstream from the confluence with the Green River (0 km).

4.5.3.2. Biological Properties There are two food sources for the consumers in any river system. These are allochthonous and autochthonous organics.

A. Allochthonous Food Webs In Figure 4.5-4, the concentrations of two fractions of particulate organic matter (POM) are plotted by distance from the confluence. Inspection of these curves indicates that major input of CPOM (coarse particulate organic matter; twigs, branches, leaves, etc.) occurs between 100 and 150 kms from the confluence. This area corresponds to the largest concentration of cottonwood bottoms. These coarse particles are colonized by bacteria and reduced to FPOM (fine particulate organic matter) by abrasion, animal feedings, and microbial metabolism. The downstream transport of this material (gms detritus/m^3) can also be seen in Figure 4.5-4. The temporal pattern of this drifting organic matter indicates that the mass of organics does not increase at time of leaffall, but during springtime lower basin runoff. This represents the time when dry washes and riparian land which had been collecting litter during the fall and winter were purged by flooding.

The rate at which CPOM is converted to FPOM by bacteria and macroinvertebrates has been empirically determined. The rate of organic decomposition was significantly related to temperature (Figure 4.5-5).

Associated with these external organic sources are macroinvertebrate food webs. The distribution of the major macroinvertebrate functional groups (Cummins 1973) along the White River continuum can be seen in Figure 4.5-6. The biomass of macroinvertebrates generally decreased from the upper stretches to the confluence. Of the invertebrates in the lower stretches of the river and where stable substrate was available, filter

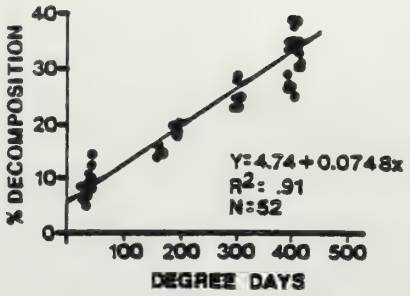

Figure 4.5-5 Leaf decomposition studies conducted in the White River (October, 1981 - April, 1982) at km 79.

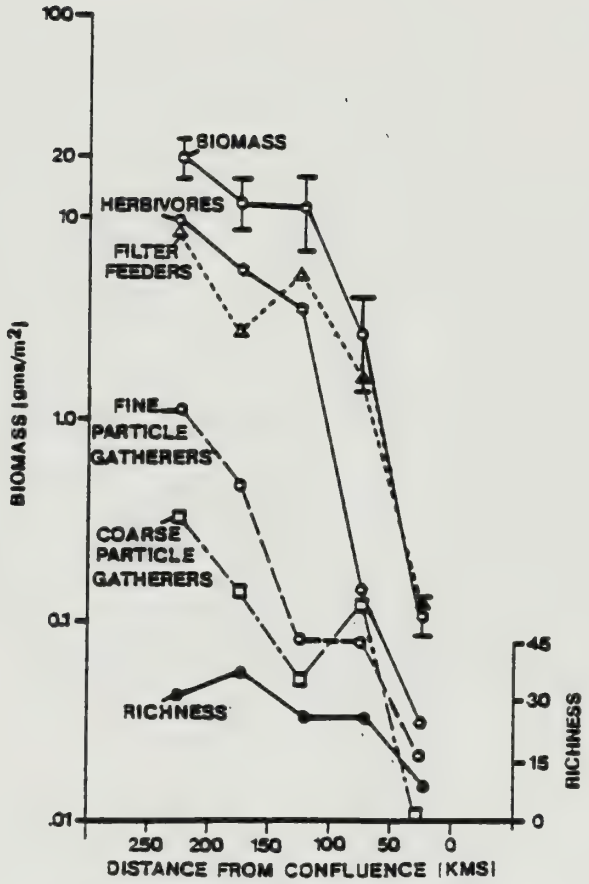

Figure 4.5-6 The distribution of benthic macroinvertebrate functional group biomass and species richness by distance from the confluence with the Green River. Data collected on the White River, July - September, 1981.

feeders had the highest biomass, corresponding to higher concentrations of FPOM in the water. Macroinvertebrates which actively gathered particles from the stream bottom showed decreasing biomass downstream. However, these functional groups did have increased biomasses corresponding to areas of allochthonous organic inputs and stable substrates.

B. Autochthonous Food Web The production of biomass by hydrophytes and algae comprised the basis of the autochthonous food web. Studies near the site of the proposed White River Dam indicated that periphyton biomass was related to substrate type (Figure 4.5-7). The higher biomass occured in sections of the river dominated by large, stable substrate. This will be discussed further in a later section. It is believed that the dominant physical factors such as greater substrate stability and greater light penetration (USFW 1981) have resulted in a greater algal biomass in the upper strata of the White River. These periphytic biomass levels were believed to have decreased from headwater to confluence for this river system as a whole because of less available substrate downstream. This, combined with higher turbidity downstream, resulted in less available autochthonous production in the lower stretches of the river (below 60 kms). The macroinvertebrate data (Figure 4.5-6) supported these conclusions. In the upper sections of the river (240-150 kms), macroinvertebrate hervibores were dominant.

C. Macroinvertebrate Drift In the White River, the drift of macroinvertebrates appeared to be a function of distance upstream (Figure 4.5-8). Density of insects declined from headwaters to confluence while species richness remained relatively constant. In the upper strata of the river (above 150 kms), the dominant drift organism was Tricorythodes,

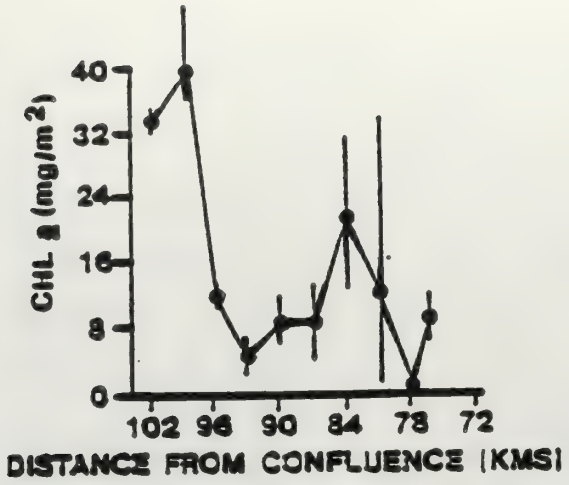

Figure 4.5-7 The distribution of benthic periphyton by river km from Asphalt Wash (km 72) to Hell's Hole Canyon (km 102) in the White River. Data collected in April 1981.

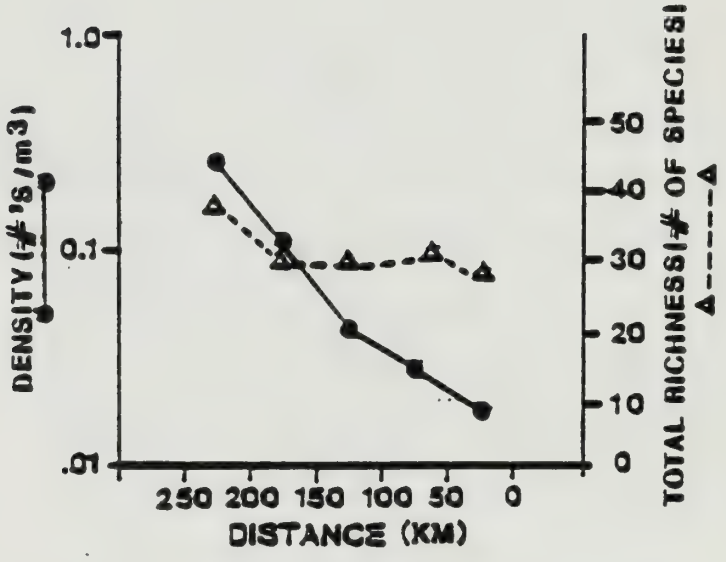

Figure 4.5-8 The density and species richness of drift insects located in the White River. Data collected between July and September 1981.

an herbivore. In the middle section of the river (96-150 kms), all drift species were evenly distributed among functional groups; whereas in the lower sections, Limnephilus, an omnivore, dominated. A comparison of drift richness to benthic richness (Figure 4.5-9) indicated that in the lower strata of the river (below 150 kms), the upstream contribution of drift richness and terrestrial species became extremely important.

4.5.3.3. The White River Fishes An extensive survey of the distribution of fish in the White River from April to September, 1981, indicated that a distinct longitudinal distribution of the endemic (speckled dace, flannelmouth sucker, bluehead sucker, Colorado squawfish, and the roundtail chub) and the introduced species (red shiner, channel catfish, and the fathead minnow) existed with a marked separation in the distribution of the two groups. The density of these fish by distance can be seen in Table 4.5-3. Of the endemic species, speckled dace and bluehead suckers were dominant with the roundtail chub being least abundant. Red shiners were the dominant introduced species. The relative densities of the fish captured expressed as a percent of the total numbers of that species by longitudinal distance can be seen in Figure 4.5-10. Each species exhibits a general longitudinal trend with a distinct separation of introduced and endemic fish. The endemics dominated the upper reaches of the river while the introduced species were dominant in the lower reaches.

The trophic interrelationships of the fish in the White River were determined by comparing fish stomach contents (Figure 4.5-11) to benthic or drift invertebrate samples taken at the same location. A linear food

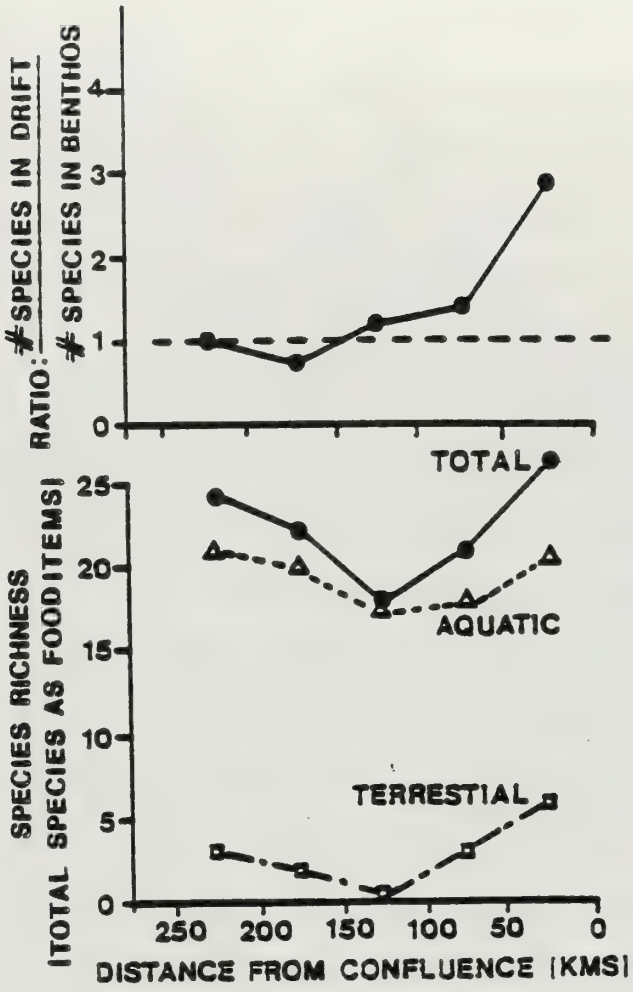

Figure 4.5-9 The species ricnhess of aquatic, terrestrial, and total fish food items and ratio of macroinvertebrate species richness in the drift to species richness in the benthos as a function of distance from the confluence with the Green River.

Table 4.5-3. Density of fish (#'s/m^2) by distance from the confluence of White River with the Green River.

KMS FROM CONFLUENCE		ENDEMIC*				INTRODUCED*		
		SD	RT	FM	BH	RS	CC	FH
241 - 251	YOY	0.115	0.006	0.044	0.018	0.000	0.000	0.005
	A	1.089	0.003	0.045	0.075	0.010	0.000	0.005
215 - 150	YOY	0.006	0.002	0.020	0.021	0.000	0.002	0.000
	A	0.914	0.030	0.082	0.146	0.024	0.000	0.004
150 - 96	YOY	0.006	0.001	0.000	0.000	0.018	0.014	0.000
	A	0.688	0.075	0.059	0.006	0.195	0.000	0.001
96 - 35	YOY	0.022	0.002	0.002	0.002	0.614	0.015	0.000
	A	0.108	0.020	0.040	0.030	0.616	0.002	0.002
35 - 0	YOY	0.013	0.000	0.001	0.000	0.459	0.017	0.000
	A	0.069	0.004	0.025	0.006	0.254	0.014	0.000

Note:

SD - speckled dace
RT - roundtail chub
FM - flannelmouth sucker
BH - bluehead sucker
RS - red skiner
CC - channel catfish
FH - fathead minnow

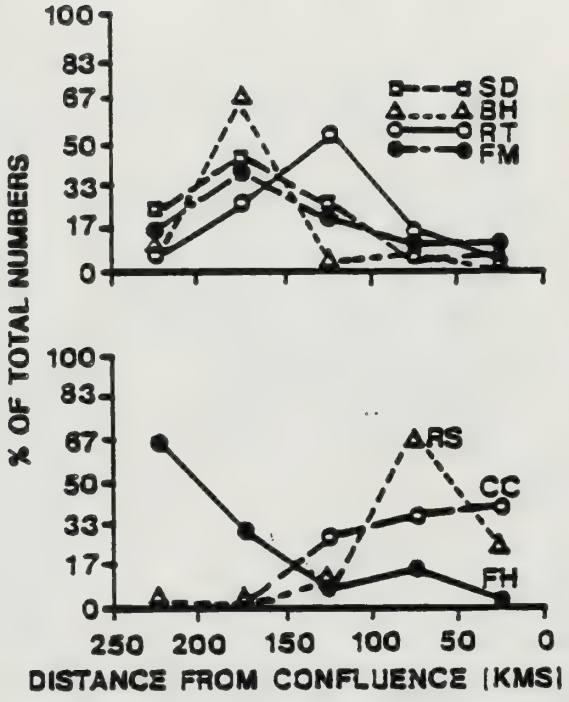

Figure 4.5-10 The percent of the total river community of species as a function of the distance from the confluence with the Green River. Data for Colorado squawfish are omitted.

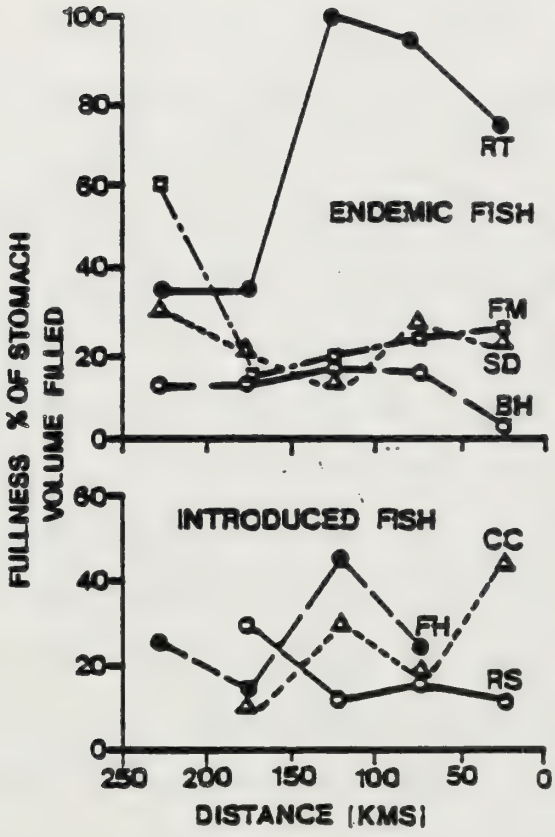

Figure 4.5-11 The percent fullness of stomach volumes for native and introducted fish collected in various sections of the White River.

selection index was calculated to determine food selection or preference (ERI 1982). The percent of total food volume contributed by periphyton was also determined (Table 4.5-4).

The bluehead sucker has been classified as a bottom feeder, scraping algae and other organisms from rocks and boulders with chisel-like horny ridges inside each lip (Sigler and Miller 1963). This appears to be true for the bluehead suckers located in the White River. They reach maximum densities between 150-215 kms and have between 30-60 percent of their food volume as algae. The necessity of periphyton for this species can be seen by the lack of algae in the stomachs of those fish caught in the lower sections of the river and the general lack of fish from this area (<5 percent of the total numbers captured). The flannelmouth sucker has also been classified as an herbivore (Ellis 1914). In the White River, they were found to be more omnivorous in feeding habits.

The distribution of speckled dace indicated its preference for the upper sections of the river. The river was characterized by swift current, large substrate, and moderate-sized pool-riffle type habitat. The fish was omnivorous, feeding on algae, detrital materials, and smaller aquatic invertebrates. The linear food selection index indicated that speckled dace, flannelmouth suckers, and bluehead suckers had a strong avoidance of Ephemeroptera and a strong preference for Chironomids. These fish also had their greatest percent fullness in the upper reaches of the river.

Although the roundtail chub exhibited a similar distributional trend, its food habits were completely different. The percent fullness of fish stomachs reached a dramatic peak from the middle to the lower section of

Table 4.5-4. The percentage of total food volume contributed by periphytic algae by species for each strata. Fish for stomach analysis were collected from the White River, 1981.

KMS FROM CONFLUENCE	ENDEMIC*				INTRODUCED*			DOMINANT SUBSTRATE**
	SD	RT	FM	BH	RT	CC	FH	
241-215	12%	0%	34%	23%	0%	0%	16%	38% GR 41% RU
215-150	23%	7%	17%	33%	0%	0%	0%	46% GR 25% RU
150- 96	29%	9%	18%	62%	1%	14%	0%	42% GR 26% RU 23% SI
96- 35	11%	23%	27%	6%	41%	48%	35%	36% SA 29% GR 18% RU 18% SI
35- 0	10%	0%	10%	16%	11%	6%	0%	83% SA 10% GR 7% SI
TOTALS	18.5	9.7	19.5	21.7	25	10	16	

Note:

*SD - speckled dace
*RT - roundtail chub
*FM - flannelmouth sucker
*BH - bluehead sucker
*RS - red skinner
*CC - channel catfish
*FH - fathead minnow

**GR - gravel
**RU - rubble
**SI - silt
**SA - sand

the river. The types of food items indicated that in the sections of the river where feeding was greatest, benthic insects and algae were found as diet items, suggesting bottom feeding. However, in areas where periphyton was most dense, only insects were found in stomachs, indicating drift feeding behavior.

The fathead minnow and channel catfish had densities corresponding to only one percent of the total numbers of fish captured. The fathead minnow was found only in the upper section of the river. Although in the same frequency, the distribution of channel catfish was the opposite of the fathead minnow (Figure 4.5-10). The channel catfish has been introduced into almost all drainage systems in the United States (Minckley 1973). These fish did not appear to specialize on a particular food item, feeding upon a variety of items in the same frequency found in the ambient environment.

The red shiner was by far the most abundant introduced species found in the White River. The red shiner was most abundant in the lower sections of the river. From stomach data, it appeared to be an omnivore. Pflieger (1975) has indicated that this species feeds by sight and can take food items from the water column or the benthic region. In the lower reachers of the river, their diets indicated that this species feeds primarily on drifting insects.

In summary, the source of food for the fish in the upper reaches appears to be both from the drift, benthos, and terrestrial insects (Figure 4.5-9) with some fish preferring one location over the other. However, in the lower reaches, diet richness of all fish is greater than the richness of the benthos. It appears that the downstream migration of

insects (drift) is very important in the food habits of the fish in White River.

It is felt that the White River Continuum exists as a result of changes in gradient, substrate distribution, algal primary production, detrital processing and export, macroinvertebrate functional groups, and fish distributions. These results are summarized in Figure 4.5-12.

4.5.4. Spatial - Temporal Dynamics

4.5.4.1. Physical Properties Over certain reaches of the river, particularly those located from the confluence with the Green River to Rio Blanco Lake (240 kms), the White River appears to be a meandering river flowing within a meandering valley (Lyle 1980). This would suggest that the river may be under fit (flowing in a valley that was produced by a much larger river) (Dury 1964). The ratio of the White River valley width to the valley meander wavelength (from USGS topographic maps) has been shown to match the empirical relationships documented by Leopold and Wolman (1957), and thus supports the contention that this river valley is, in fact, an old stream bed. Because of this under fitting, the present floodplain within the river valley is five to six times the river width. This has resulted in an extensive amount of river bottom land and the development of a major riparian community. In total, 2450 ha of riparian floodplain exist from the Colorado border to the White River's confluence with the Green River. Approximately 1500 ha are located adjacent to Tracts Ua and Ub.

Within this geomorphological setting, certain physical abiotic factors play a dominant role in shaping the structure and function of the

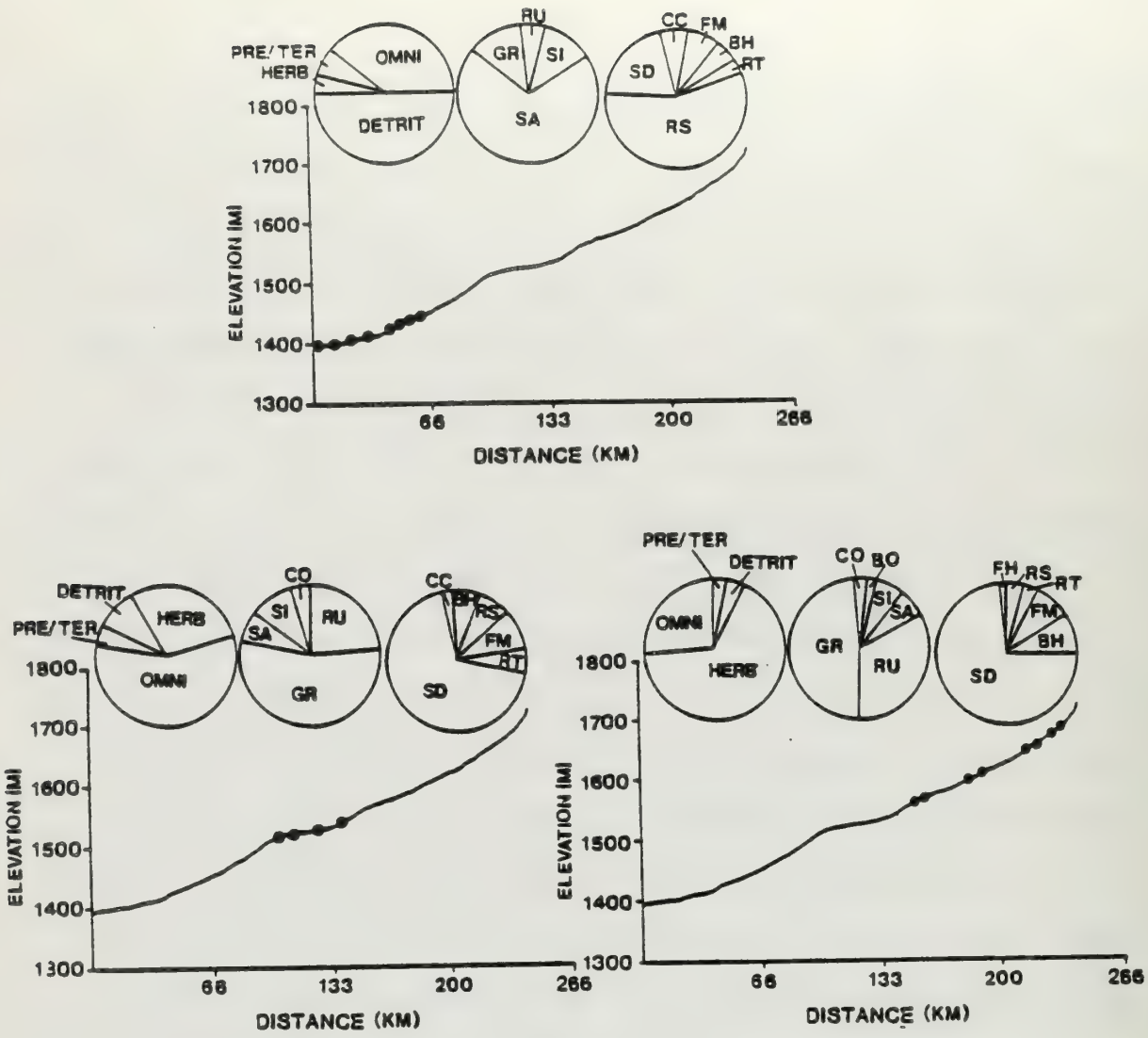

Figure 4.5-12 The distribution of fish species, macroinvertebrate functional groups, and substrate throughout the White River (sample sites denoted by dots). Each plate represents the percent of total number for that section of the river noted.

ecosystem. Within this stretch of the White River, these dynamic factors are: (1) surface flows from adjacent watersheds into the river, and (2) upstream contributions.

A. Watershed Contributions The contribution of water and materials to the White River from Evacuation Creek and the dry washes occurs from periodic, intense, and localized storm events. The data indicate that a series of storm events during March and April, 1979, produced obvious changes in the physical conditions of Evacuation Creek and the White River. These storm events produced 1.02 inches (2.6 cm) of precipitation. This rainfall increased the flow of Evacuation Creek from approximately 8 cfs to over 32 cfs. The total suspended solids increased from 16 mg/l to 65,000 mg/l. Flows in the White River increased from 1,000 cfs to 1,800 cfs and total suspended solids from 200 mg/l to 4,500 mg/l over this same time period. During October 1981, a series of similar storm events increased the flows in Evacuation Creek and the White River by over 500 percent. This increase in flow resulted in a change of the abiotic and biotic components of this river ecosystem.

B. Upstream Contributions Major river systems that flow through arid regions usually have their origins in distant places of higher elevation that receive comparatively high, persistent or seasonal precipitation. Such is the situation with the White River.

The upstream contribution has three distinct components (WRSOC 1974-1982). The first has been defined as normally occurring baseflow. The second input in caused by spring melting of lowland snow packs (lower basin runoff). This input represents only a small portion of the spring runoff, but the nutrient content (nitrogen and phosphorus of this water

source is extremely high (Figure 4.5-13). These nutrients are important to the growth of aquatic periphyton. The third input is the snowmelt from higher elevations (upper basin runoff). This water source is large and causes extensive dilution of total dissolved substances. Concurrent with these changes in flow, are the changes in total suspended sediment. Examples of these upstream contributions for 1981 can be seen in Figure 4.5-14. The two dynamic factors previously mentioned are extremely important because they determine the abiotic or physical structure of this section of the river. Based upon the existing limits of these dynamic factors, this abiotic structure can be defined.

C. Abiotic Structure The penetration of light (defined as the extinction coefficient "k") has been shown by WRSOC to be related to total suspended solids (Figure 4.5-15). This interrelationship combined with the total suspended solids in the river system has allowed the calculation of the depth to which one percent of the surface light will penetrate based on TSS levels (Figure 4.5-16). This light level has been empirically determined to be the level at which primary production will be limited. Using all available data, it has been determined that between 1974 and 1981, the one percent light level has varied between a depth of 0.8 and 25.8 cms. In general, the calculated light penetration is poor between April and July (less than 10 cms in depth) and greatest between September and January (greater than 40 cms). Data for TSS and associated depths to which light penetration occurred during 1981 are shown in Figures 4.5-17 and 4.5-18. Because light is related to primary production, the present seasonal turbidity trends are extremely important in the interpretation of primary production.

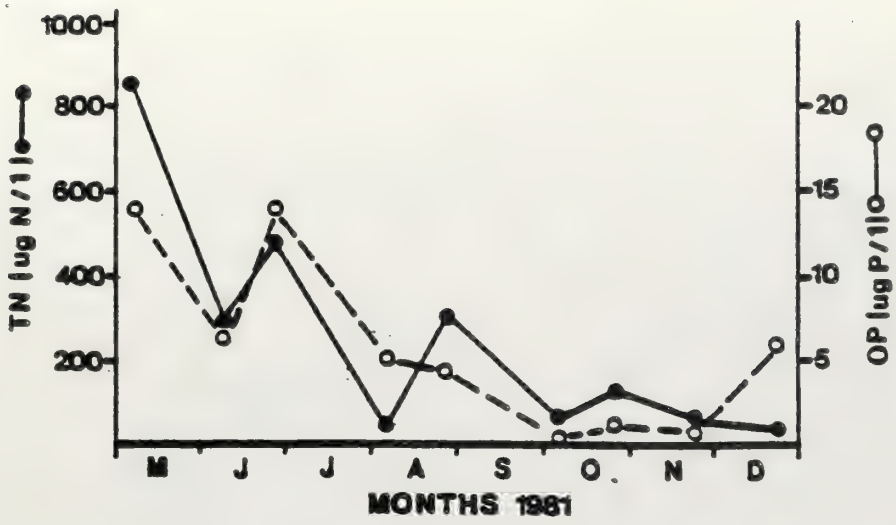

Figure 4.5-13 The concentration of orthophosphate and total inorganic nitrogen (NH_3 + NO_2 + NO_3) in the White River during 1981. The data represents five-day averages (monthly) at Southam Canyon (km 79).

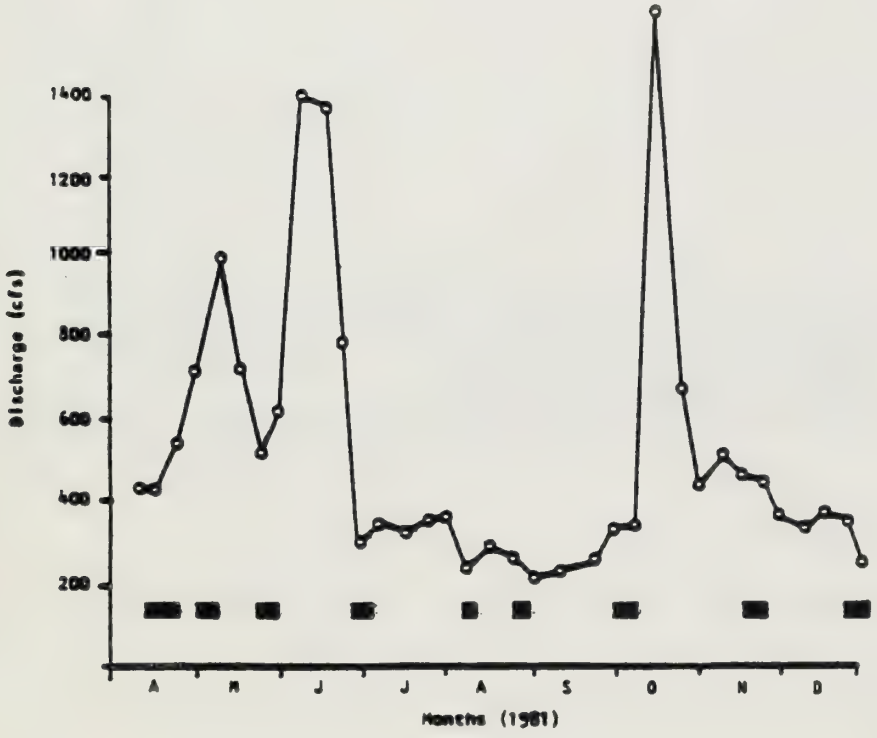

Figure 4.5-14 Discharge in the White River during 1981.

■ Indicates sample period for aquatic biology monitoring.

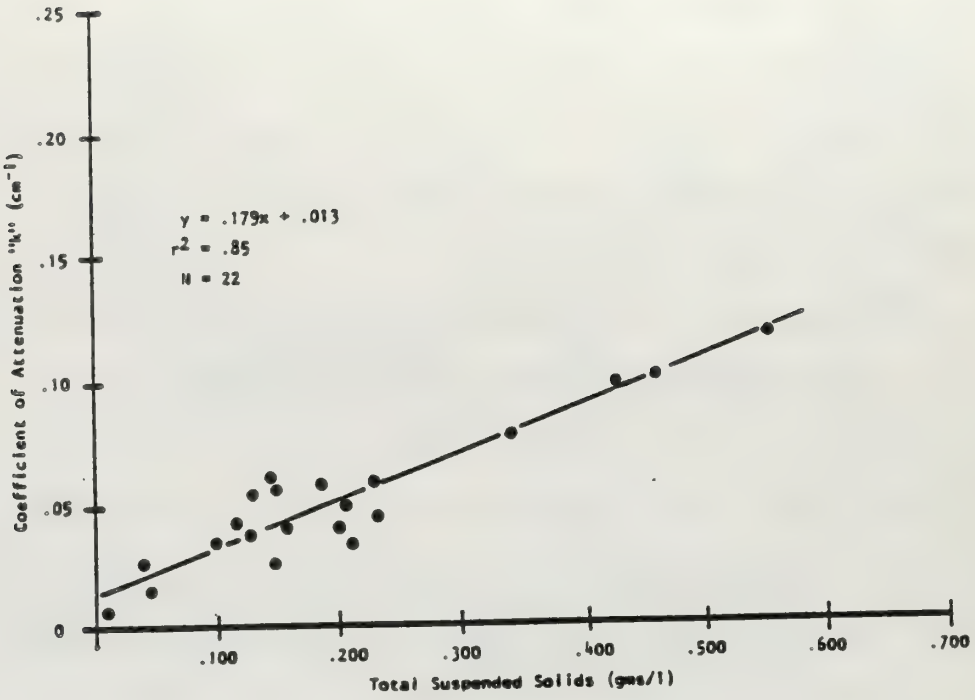

Figure 4.5-15 The empirical relationship developed between the coefficient of attenuation ("k") and total suspended solids (TSS) expressed as gms/1. Data collected from the White River, 1981.

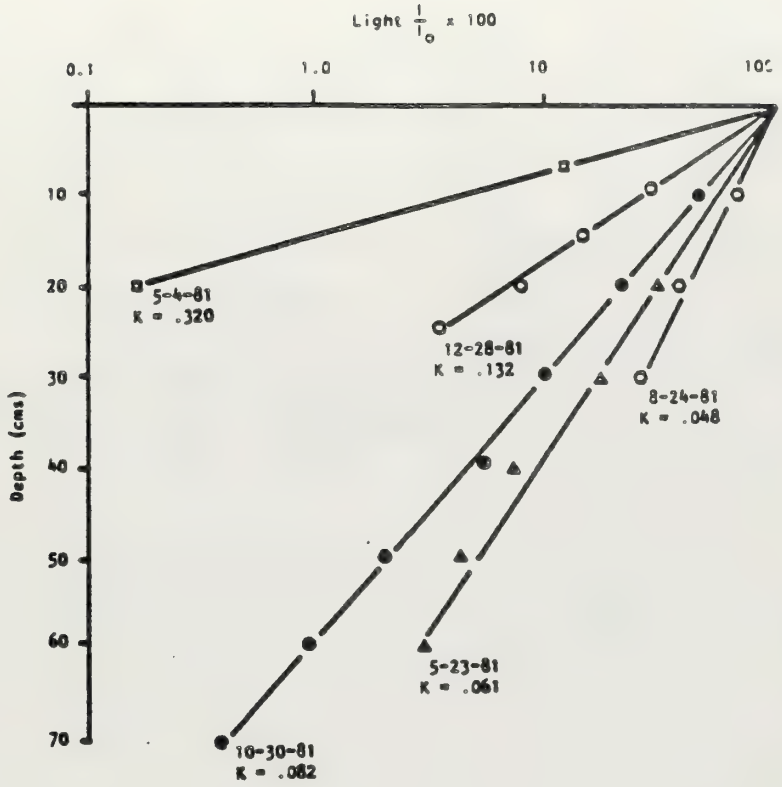

Figure 4.5-16 Attention coefficients and light profiles for different sample periods during 1981.

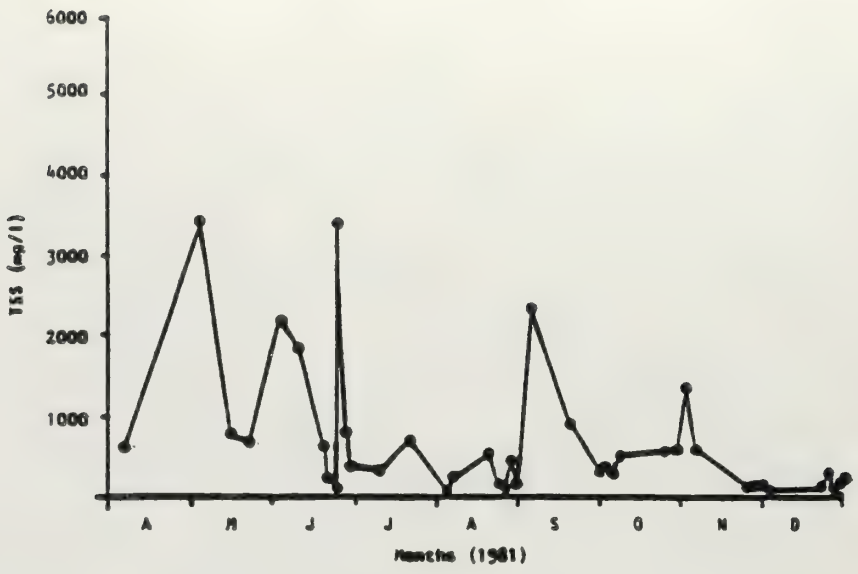

Figure 4.5-17 Total suspended solids (TSS) by sample dates for the White River during 1981.

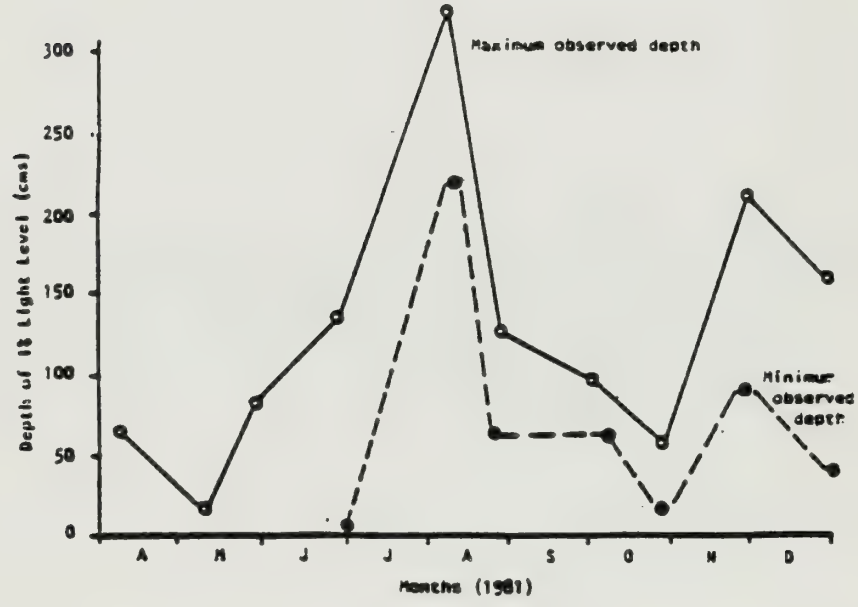

Figure 4.5-18 Depth of light penetration to the one percent light level in the White River during 1981.

The description of the White River in terms of its abiotic structure and the associated biological interrelationships must also include the two major fluvial geomorphologic components: (1) The river must be defined in terms of its hydraulic geometry, and (2) its water characteristics. The factors necessary for these descriptions and their quantification are discussed below.

The hydraulic geometry or the determination of the physical factors which form the morphology of the river bed are extremely important. The major physical impact of current and turbulence is the shifting and restabilization of the bed configuration in the White River. This process not only produces molar action which may physically damage animals and plants, but also modifies certain habitat types (pools, runs, riffles, and substrate configuration). Periods of high discharge or storm events (dynamic abiotic inputs) will produce greater habitat modifications than the normal, baseflow water discharge levels. The discharge patterns found in the White River combined with channel geomorphology have produced several basic habitat types.

D. Suspended Solids and Sedimentation Two of the major abiotic forcing factors in the White River system are upstream inflow and watershed contributions. These processes influence the silt load and sedimentation rate in the White River.

The effect of sediment brought into the White River is related to current velocity and sediment transport. For example, changes in water velocity in the absence of any change in sediment load have been shown to increase the amount of periphyton production. Conversely, an increase in sediment load without a consequent change in current velocity, can reduce light penetration, and hence, periphiton production.

During a 1981, a detailed study was undertaken to determine the impacts of suspended sediment upon the transparency of light and the concurrent relationship in benthic photosynthesis. A summary of these results indicated that suspended sediments alone could indirectly affect the rate of algal production by a concurrent reduction in light penetration to the stream bottom. The relationship between the total daily production rate of photosynthesis (mg O_2/m^2/day) and daily light intensity (lux) can be seen in Figure 4.5-19. A comparison of the assimilation ratios (mg O_2/mg Chl a/hr) for a spring and fall algal community indicated that the spring communities were adapted to high light intensities while the midsummer communities were grown under lower light levels. This is consistent with the patterns of turbidity and light penetration observed in the White River.

E. Flow The relationship of flow and scouring effect of suspended sediments has been documented by McIntire (1965). It is apparent that high suspended sediments are associated with elevated flows in the White River. The impact of these abiotic factors upon the algal standing crop and production has been documented by the reduction in chlorophyll a during April and October, 1981 and reduced rates of production during periods of high turbidity. Such scouring or "molar action" may cause similar reductions in the populations of benthic macroinvertebrates.

4.5.4.2. Initial Field Investigation and Site Selection Twenty-nine cross-stream transects were surveyed from bank to bank in the White River during April, 1981. These transects were located in groups of three at two-mile intervals between Hell's Hole Canyon (km 102) and Asphalt Wash

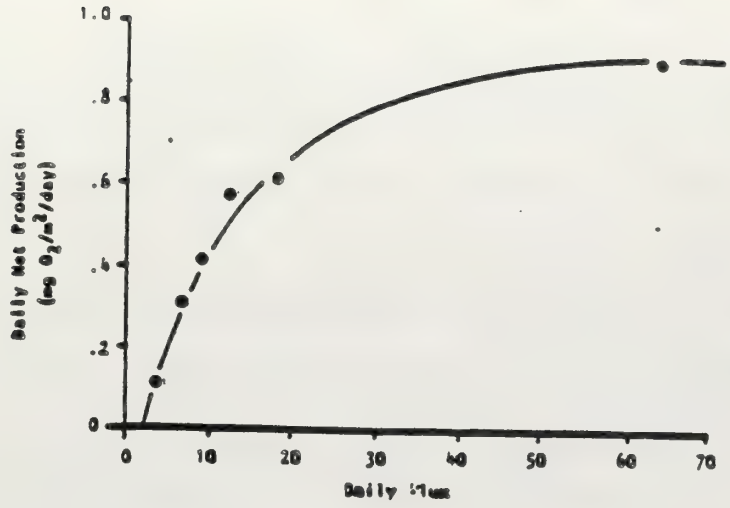

Figure 4.5-19 Relationship between daily net production and total available light energy for production-respiration experiments conducted in the White River during 1981.

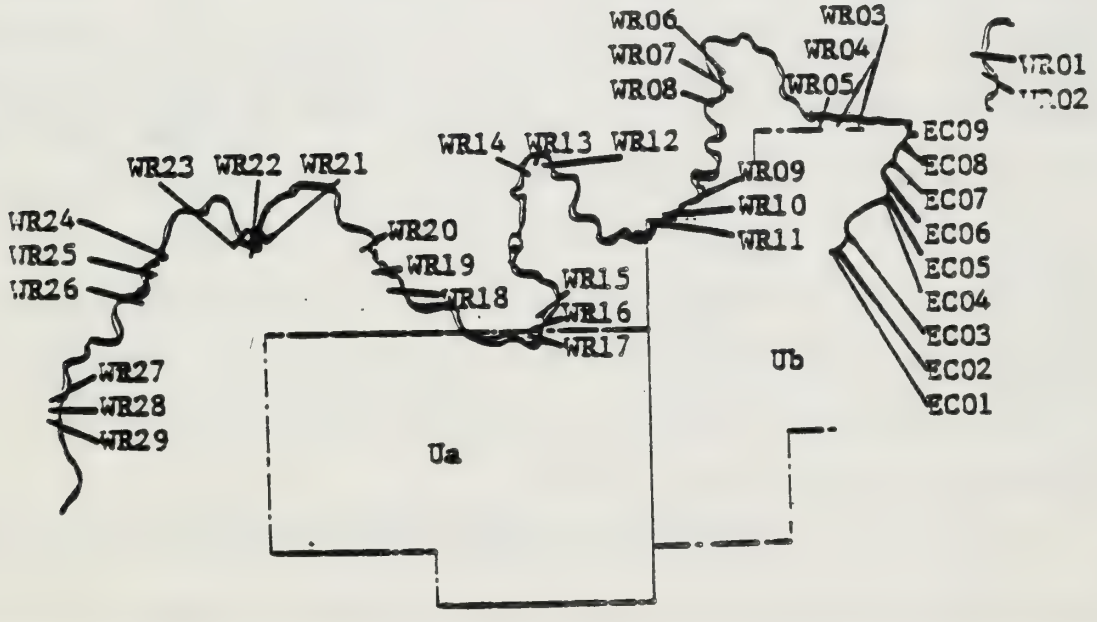

Figure 4.5-20 Map showing locations of all transects used in the initial and monthly field investigations.

(km 72) (Figure 4.5-20). Nine transects in groups of three were surveyed in the lower mile of Evacuation Creek. At each transect, complete profiles of the streambed were surveyed and combined with data collected on velocity, substrate, gradient, sediment, percent light transmission, and chlorophyll a.

Following this survey, data were subjected to "Clustar" analysis using the technique of Marshall and Romesburg (1979). The objective was to determine the distribution of basic stream habitat types. In the White River, the transects were divided nearly evenly between two major categories of which 14 transects are designated as "pool" and 15 as "riffle." This implied that this section of the river is evenly divided between the two types of habitats. An ANOVA verified the output of the Clustar analysis. The riffle transects were significantly shallower, steeper in gradient, wider, and had larger substrate and algal standing crops (Table 4.5-5). In Evacuation Creek, three groups of transects emerged with which were very similar in nature except for dominant substrate and gradient (Table 4.5-6).

An analysis of dominant substrate for the 478 locations measured along the White River transects indicated that 45.2 percent of the substrate occurred in the coarser size fractions of boulder, cobble, rubble, and gravel, whereas the remaining 54.8 percent were found in the fine size fractions of sand, silt, and clay.

Transect WR18 (riffle) and WR20 (pool) are examples of the two types of habitats present within the White River. Because the magnitude and distribution of water velocities are related to substrate size, the velocity isolines in Figure 4.5-21 reflect the major differences between

Table 4.5-5 Mean of physical and biological parameters for riffles and pool/run type transects on the White River, Utah.

Parameters	Riffle	Pool/Run
No. of Transects Included	15	14
Mean Habitat Location (River Miles Down Stream from Hell's Hole Canyon)	6.5	11.2
Depth, m	0.44*	0.68
Velocity, m/sec	0.41	0.39
Chlorophyll a, mg/m^2	20.4*	9.1
Width, m	43.1*	28.8
Gradient %	1.58*	0.64
Dominant Substrate, cm	3.3*	2.1
Interstitial Substrate by Size Fractions, mm		
> 12.7	18.4*	12.2
4.0-12.7	20.1*	12.7
0.5-4.0	21.1	19.0
0.25-0.4	17.4*	30.6
< 0.25	22.8	24.8

*Significantly different @ 95% confidence interval

Table 4.5-6 Mean of physical and biological parameters for three groups of transects on Evacuation Creek. Data from initial field investigation in mid April 1981.

	Transects		
	EC01, 02	EC05, 06, 07	EC03, 04, 08, 09
Depth (m)	0.047	0.060	0.070
Velocity (m/s)	0.38	0.24	0.32
Width (m)	1.9*	4.1*	2.9*
Gradient (m/m)	0.0072	0.0067	0.0056*
Dominant Substrate (cm)	3.83*	0.42	0.49
Interstitial Sediment by Size Fractions (mm)			
> 12.7	16.3	17.0	14.5
4.0 - 12.7	33.6	24.4	28.1
0.5 - 4.0	31.8	35.0	36.9
0.25 - 0.5	11.5	12.8	12.4
< 0.25	6.8	10.7	8.2
Chlorophyll a (mg/m^2)	5.6	3.9	6.5

* Group parameter means different at $p < 0.05$ using ANOVA.

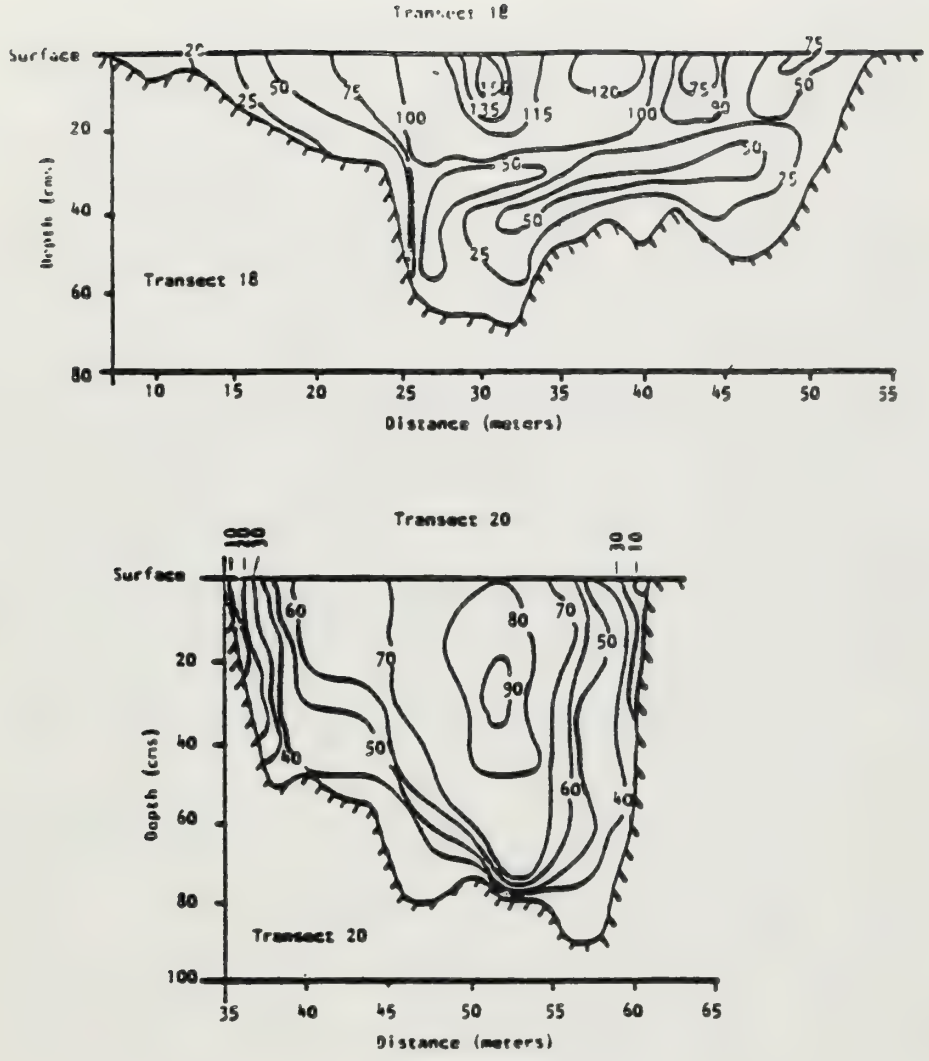

Figure 4.5-21 Velocity profiles of Transects WR18, WR20, showing velocity isolines.

these habitat types. The velocity distribution for WR18 includes a series of high and low velocity cells, indicating turbulent water movement but lower velocity cells, indicating turbulent water movement but lower velocities at the stream substrate. These low bottom velocities and turbulence reflect the dominance of this transect by larger substrates and steeper gradient. The low bottom velocities reflect a more stable microhabitat in the interstitial spaces between the larger rocks. This is evidenced further by the composition of the interstitial substrates. The riffle transect has very stable percentages of sand and silt (fractions smaller than 0.25 mm).

Transect WR20 on the other hand, with smaller substrate and a channel cross-section much like a pipe has higher bottom velocities and less stable microhabitat due to the absence of large boulders and cobble. This creates an unstable bottom with shifting sand and silt which compose the majority of substrates on this transect and exhibit large monthly changes. These relationships are true for pools and riffle in the river in general (Table 4.5-5).

Because stable substrates and light penetration are important to the success of in-stream primary production, the distribution of different substrate classes with depth was important. For example, during runoff and storm events with the large increase in suspended solids, light penetration can be limited to less than ten cms. During this time, most of the large, stable substrates do not fall into a light climate suitable for primary production. During the fall and winter months, light penetration is generally greater than 40 cms which greatly increases the available stable substrate upon which the periphyton community depends.

Water characteristics for rivers in general have been described by Gibbs (1970) as being distinguished by three basic origins for loads of dissolved substances. These are: atmospheric precipitation, rock weathering, and evaporation-crystallization processes. These processes affect the relative distribution and concentrations of the major macroelements found in the White River ($HCO_3^{-1} > SO_4^{-2} > Cl^{-1} > CO_3^{-2}$, and Ca^{+2} and $Na^{+1} > Mg^{+2} > K^{+1}$). In general, the highest concentrations of these macroelements occurs between July and February, with lowest concentrations occurring during runoff (April through June). Data from the White River indicate that both nitrogen and phosphorus are often below detectable levels and could, therefore, become limiting to primary production. During 1981, the seasonal changes of these components was extensive (Figure 4.5-13). This seasonal trend in total inorganic nitrogen (TIN) and orthophosphate was, however, periodically changed by single storm events. In the past, it has also been shown that storm events can drastically increase the concentration of certain heavy metals in the White River. For example, during a storm event in March, 1975, the dissolved copper content of Evacuation Creek increased from 6 ug/l to over 600 ug/l. The total suspended sediments also increased (200 mg/l to 10,200 mg/l). These temporal changes were also observed in the White River. Flow increased from 500 to 1,100 cfs, total suspended solids from 200 mg/l to 2,500 mg/l, and the dissolved copper increased from 4 ug/l to 340 ug/l. This phenomenon has also been noted for other metals.

Temperature is also an important physical factor in that it can both directly (biological metabolism) and indirectly (chemical precipitation) affect the structure and function of the White River. Water temperatures

reached a minimum of 0°C in December through February with ice over much of the stream. Maximum temperatures (25-28°C) occur during baseflow (July-September). It is important to note that the daily fluctuations in temperatures in the White River were as high as 13°C. These diel changes in temperature have been shown to be an important physical factor in the ecology and life history of several macroinvertebrate species. These changes in daily temperature result in higher growth efficiencies and higher species richness.

4.5.4.3. Biological Properties Within the White River continuum, the relationships between gross production and the storage, processing, and export of terrestrial organics is critical in defining the structure and function of this stream ecosystem. Furthermore, the spatial and temporal differences of these defined biological processes acting in concert with the previously described physical factors, determine the distribution of terrestrial organics and aquatic primary production. The specific food webs and their abiotic and biotic interrelationships will be discussed in more detail.

A. Autochthonous Food Web (Grazing) This food web centers around primary production by periphytic algal communities and grazing on these communities by aquatic macroinvertebrates. An example of the spatical and temporal changes in the attached algal community can be seen in Figures 4.5-22 and 4.5-23. The monthly averages for periphyton biomass in a riffle area were significantly higher during each monthly sample period when compared to a pool habitat. That runoff caused a decrease in biomass within the periphyton community in April was evident in both types of

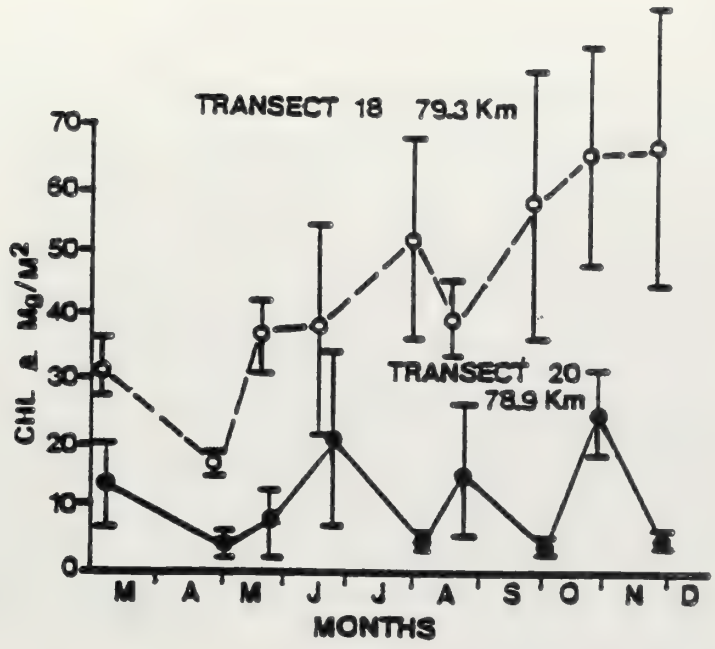

Figure 4.5-22 The temporal change in periphyton biomass at a pool transect (WR20) and a riffle transect (WR18) in the White River. Each point is a mean of five samples taken at equal distances across the river. Standard error bars are given. A significant difference between sample dates was found for Transect WR18 (α = .01).

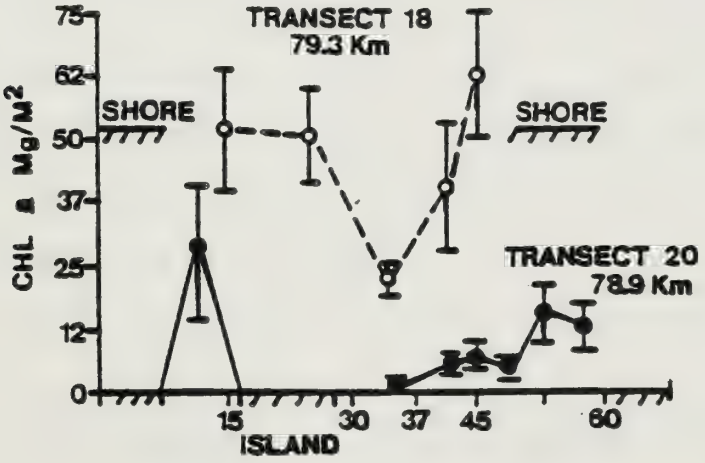

Figure 4.5-23 The spatial differences in periphyton biomass (mg Chl a/m^2) between April and December, 1981. Each point represents a 9-month average at that site with standard errors given. Both transects had significant differences by distance, α = .01.

habitats; however, the riffle habitat demonstrated the highest rate of recolonization and growth when compared to pools. The distribution of algae across the stream channel also showed significant differences (Figure 4.5-22). The shallower areas in Transect WR18 had significantly higher algal standing crops when averaged over the whole year. However, in the pool transect, the opposite trend was observed. The shallow areas had extremely low chlorophyll a values, whereas the deeper sections of the stream had the highest values. The difference between these two habitat types may be related to substrate stability. The distribution of periphyton as related to substrate size will be discussed later in more detail.

Seasonal changes in periphyton species distribution in the riffle area indicate (Figure 4.5-24) that diatoms reach their maximum numbers in early spring and late fall, with Cladophora and other filamentous green algae dominating in mid- to late summer. The blue-green algae also reach their maximum abundance in late summer, although the percentage of the total community biomass is less than twenty percent. As previously noted, the seasonal distribution of algae in the White River is identical to the seasonal changes of algae taken from the whole water samples in the Green River (Lamarra 1981). The seasonal trends in species composition and biomass levels are similar to the results of MacIntire and Pinney (1964).

In situ primary production-respiration chambers were used to estimate the amount of net and gross production and community respiration. The results of these experiments can be seen in Figures 4.5-25 and 4.5-26. The maximum amount of net and gross production (1.47 $\pm$ .22 mg

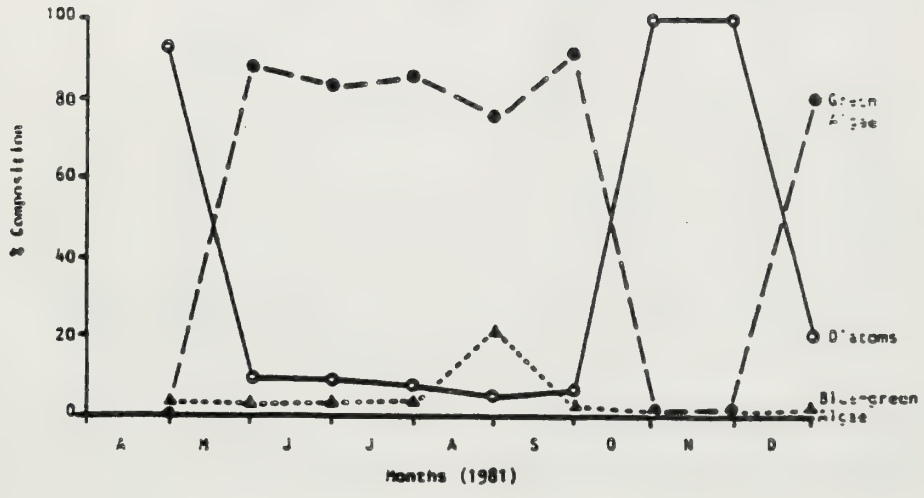

Figure 4.5-24 Percent composition of the major taxonomic groups of periphyton community based on relative volume observed in microscopic counts. Samples taken from a riffle transect, WR18, in the White River.

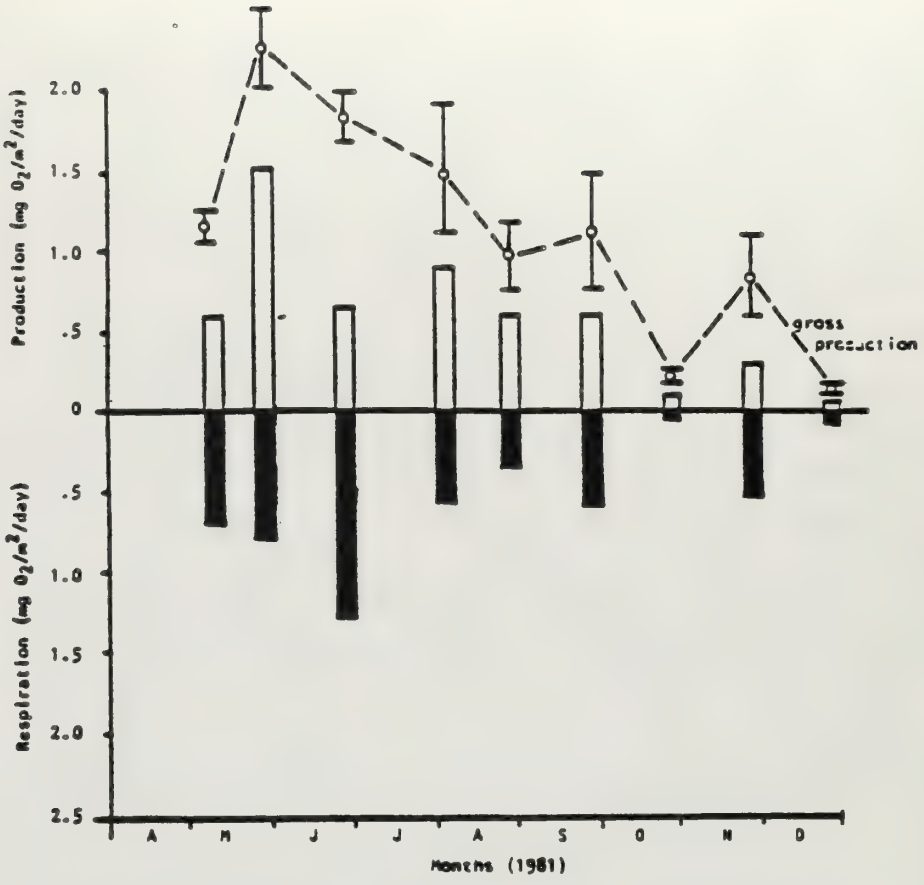

Figure 4.5-25 Gross, net production, and respiration for P/R experiments in the White River during 1981.

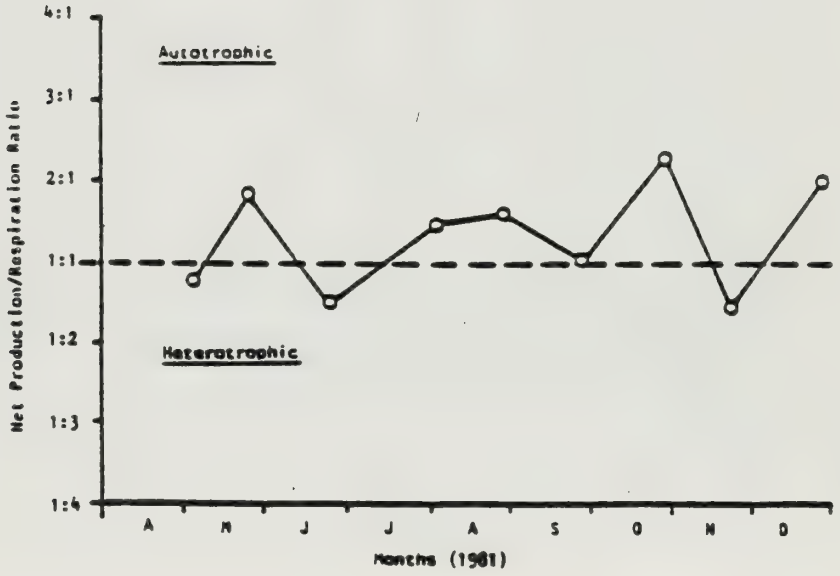

Figure 4.5-26 Net production to respiration ratio for experiments conducted in the White River during 1981.

$O_2/m^2/day$ and 2.25 $\pm$ .34 mg $O_2/m^2/day$ occurred on May 27-29, 1981 Minimum estimates occurred in October. The seasonal trends in gross primary production indicated that after a spring maximum, the levels of production steadily decreased through December. This could be due to nutrient limitation as the seasons progress. A departure from the trend . line occurred in October when values were lower than expected. This could have been due to a large storm which raised discharge levels in the river and scoured away much of the attached algae.

The ratio between net production and community respiration (P/R) (Figure 4.5-26) has been used to describe the degree of autotrophy or heterotrophy within the stream ecosystem. The White River system had three time periods where the P/R ratio was less than or equal to one. Those times corresponded to extensive storm events (turbidity) or after a period of excessively high flows (October, 1981). In general, the White River appeared to be autotrophic based upon the *in situ* production-respiration studies.

As previously noted, the light climate within the river can change drastically depending upon the turbidity of the water. A comparison between the amount of daily net production per gram of chlorophyll *a* and total available light (Figure 4.5-27) indicates that this observed relationship appears to follow the same pattern noted previously by McIntire and Phinney (1965) in laboratory stream studies.

The primary producer estimates in Evacuation Creek were based upon the biomass of periphyton. Because of the intermittent nature of the stream, samples were only collected during periods of flowing water. Mean monthly biomass values are given in Figure 4.5-28 for Transects 2

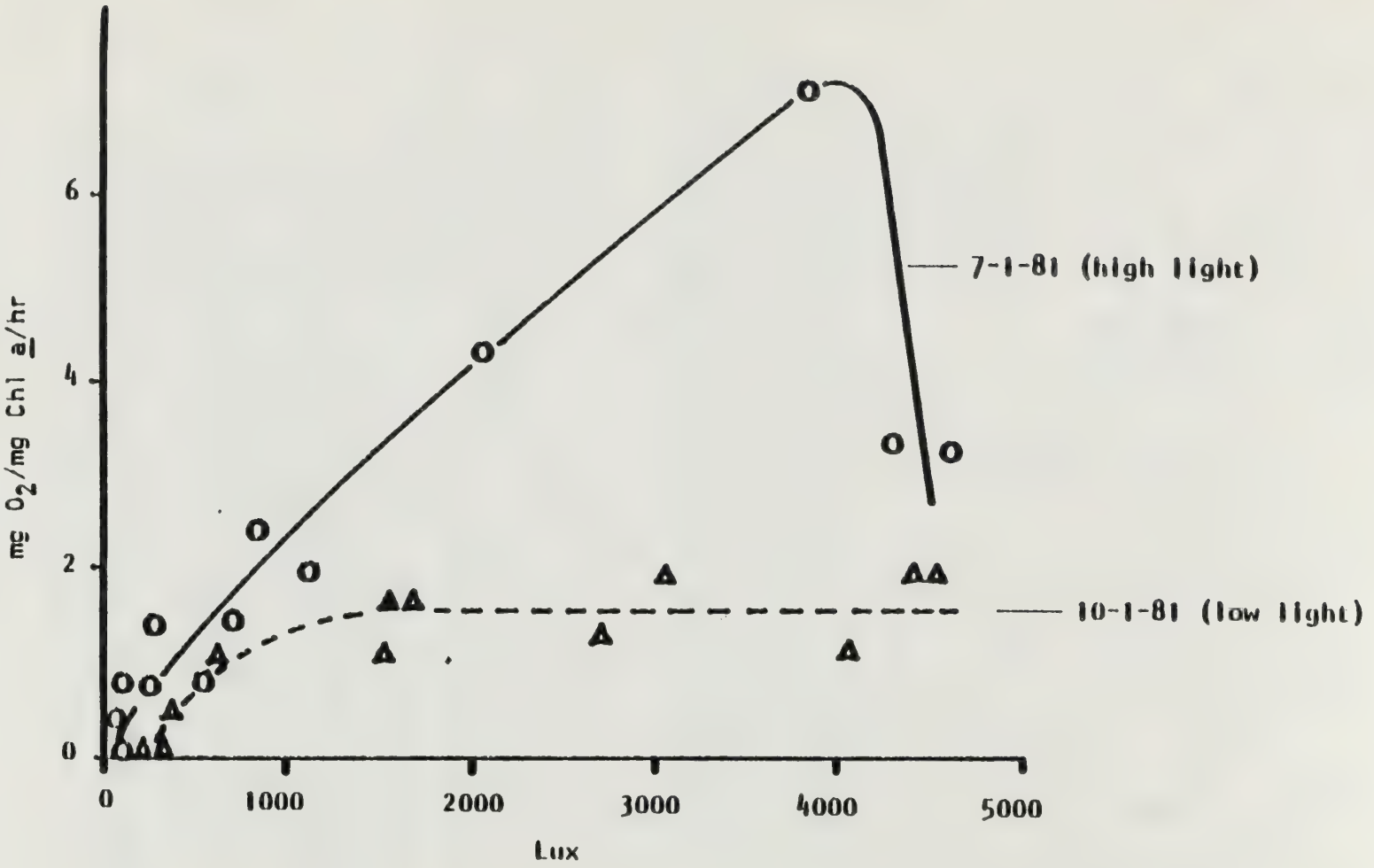

Figure 4.5-27 The specific rate of photosynthesis related to light intensity on Transect WR 18 in the White River. The data is selected from production experiments run on 7-1-81 and 10-1-81. The P/R chambers were in 10 cms of water.

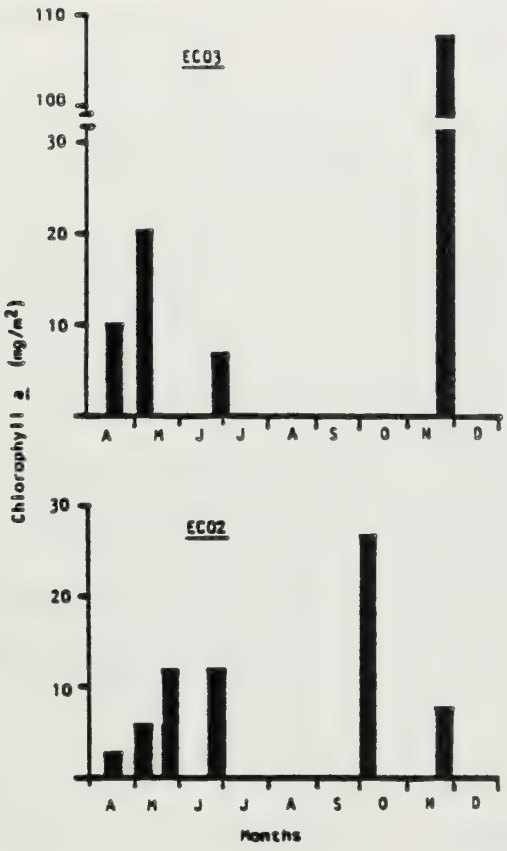

Figure 4.5-28 Mean periphyton biomass (Chl a mg/m^2) for Evacuation Creek between April and December 1981.

and 3. Maximum values occurred in November (EC03) and in October (EC02). Minimum values (excluding drought) occurred during the spring.

The macroinvertebrate distributions (expressed as biomass) in two separate habitat types near the federal lease tracts were biologically different. For example, the distribution of macroinvertebrate biomass across the stream in the riffle transect (mostly gravel, rubble, cobble, and boulder) was not found to be signficantly different throughout the year (p=.05). However, if average densities (N=5) for each sample are compared over time, significant temporal differences (p=.01) were found. Mean biomass was low (.31 gms/m^2) in early May and increased significantly through late June. Average size also increased dramatically during this time period. Another significant increase occurred by early August (p .01) reaching a maximum biomass of 10.9 gms/m^2. Biomass decreased through October after this increase. This habitat type proved to be extremely stable, with a well-defined community structure and function (see Figure 4.5-29).

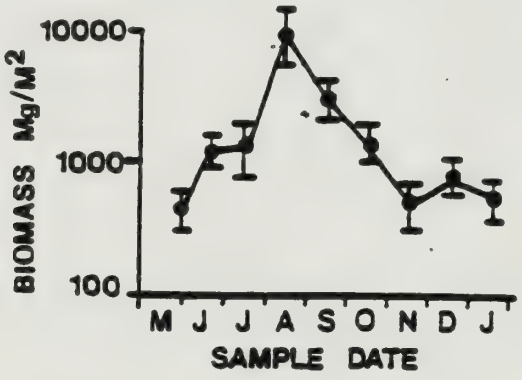

Figure 4.5-29 The macroinvertebrate biomass estimates for each sample date (N=5) in the White River at km 79. Data collected between May and December, 1981. Significant differences were found between sample dates (α = 0.1).

The pool transects in the White River are characterized by shifting sand along each side of the thalweg, with armored substrate in the deepest location (clay with a cobble or rubble matrix). Because of this varied habitat, significant differences in biomass were found across the stream. Maximum biomass levels (.55 gms/m^2) were much lower than in riffle habitats.

These differences were extremely transitory between sample periods. The data indicates that periodic storm events or runoff removes the majority of the macroinvertebrate community. The reestablishment of this community after these unpredictable events occurs almost immediately with increasing species richness developing the longer the period between storms.

An ephemeral side channel was also sampled because of its proximity to the pool habitat. Water was in the channel from May to July, 1981. The richness of macroinvertebrates was low (one or two functional groups); however, the biomass was the highest recorded at any sample site (56.0 gms/m^2 in late June). This habitat type, although highly transitory, is extremely productive and may play an important role in the river system.

The structure of the macroinvertebrate community is also diverse, with all functional groups present. An example of the temporal change in these groups in a riffle habitat can be seen in Figure 4.5-30. The relative densities of the herbivores reach a maximum in September and October, and minim m in July and November. It is interesting to note that these periods of low densities correspond to periods of changing algal community structure. The biomass of herbivores exceeds that of

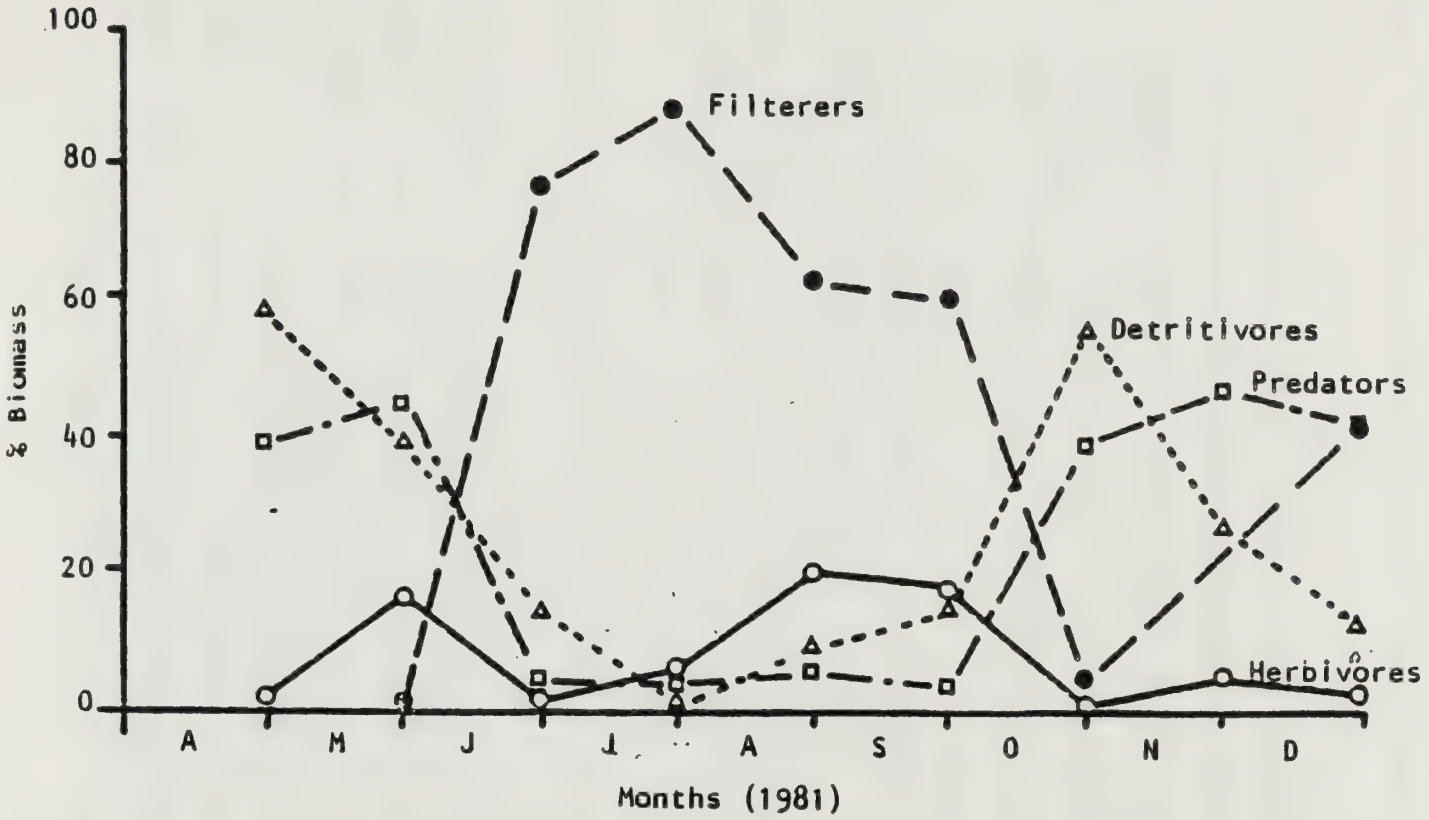

Figure 4.5-30 Percent composition of macroinvertebrate community by functional group for Transect WR 18 during 1981.

detritivores during August, September, and October. Low detrital input and high periphyton production (P/R>1) are believed to be the possible causes. The filter feeding macroinvertebrates had their distributions almost identical to that of the green algae. This functional group which has the highest biomass may have been eating algae or detritus caught in the long filamentous green algae (primarily Chadophora), which dominated the primary producers community at that time.

The macroinvertebrate community in Evacuation Creek was found to be similar to the backwater community at Transect WR20.

Seasonal trends in biomass and density fluctuated greatly with highest values observed at these sites being similar to peak values from the White River. The detritivore functional group dominated in all sample periods with predators and terrestrial insects being the only other groups present.

Drift samples taken during the first sample period indicated that Evacuation Creek had higher numbers of drifting insects per m^2 cross--section per hour than did the White River. Species richness in both the benthic and drift samples were lower in Evacuation Creek compared to the White River.

B. Allochthonous Food Web (Detritus) The detrital food web in the White River changed dramatically during the year (Figure 4.5-31). It has been shown (ERI 1982) that the coarse particle organic load (1 mm) in the vicinity of the tracts decreased from 500 kgms/day during runoff to less than 100 kgms/day during the remainder of 1981. The highest mass of CPOM entered the stream during the periods of runoff (May-June), being occasionally supplemented by storm events. The input of the CPOM during

Figure 4.5-31 The monthly mass of organic drift (>1 mm) in the White River during 1981. Data collected at km 100.

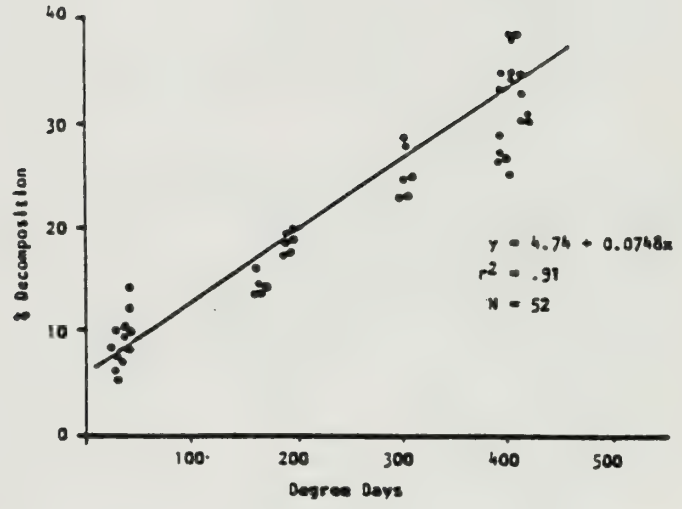

Figure 4.5-32 Leaf decomposition studies conducted in the White River (October, 1981 - April, 1982) at km 79.

leaf fall (September-October, 1981) was reflected by the change in the CPOM standing crop at the transects studied (primarily Transect WR20, km79) as well as the amount obtained in the drift nets. These high values during September-October are believed to be the result of cottonwood leaves settling in the slower water of this habitat type. The input and processing of these food stuffs were evident by the relative densities of the detritivores (Figure 4.5-30). A temporal change to the filter-feeding functional group of macroinvertebrates may also be the result of the processing of CPOM to FPOM. This period of time also had the highest number of degree days, and thus, an increased rate of decomposition (Figure 4.5-32).

4.5.4.4. Physical-Biological Interactions The interrelationships between the abiotic and biotic components of the river system are important in determining the structure and function of the White River. A brief description of how the abiotic or physical environment affects the biological community and how this physical environment may change because of naturally occurring conditions is presented below.

The stability and composition of the substrates described in the White River are dependent upon current velocity and influence the type of organisms which use the benthic region for attachment (periphyton and macroinvertebrates). Substrate size also determines the size and density of organic particles (food for higher organisms) caught within pore spaces. The effect of substrate size upon the distribution of detritus and species richness of organisms within the White River can be seen in Figure 4.5-33. The distribution of all organisms (algae, macroinverte-

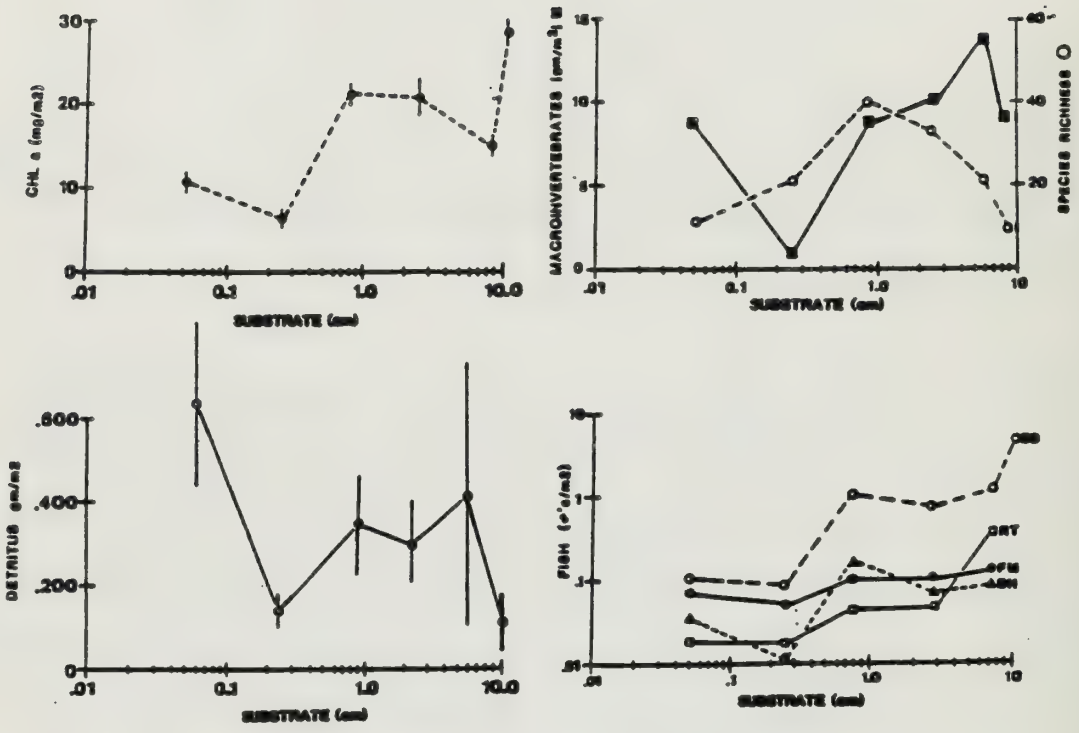

Figure 4.5-33 The distribution of chlorophyll a (mg/m^2), macroinvertebrates (gms biomass/m^2), detritus (gms/m^2), and fish (#'s/m^2) by substrate sizes in the White River, Utah. Bars denote 95% confidence intervals. SD = speckled dace, RT = roundtail chub, FM = flannelmouth sucker, BH = bluehead sucker.

brates, and fish) appears to be similar. Sand is avoided by all organisms while the intermediate substrates are preferred (gravel, rubble, and cobble).

Habitats characterized by fine grained substrates (silt and sand) support the fewest number of species. For example, a burrowing species, Chironomus, comprises more than 50 percent of the invertebrate populations in areas characterized by these soft substrates. Filterers are least important on the fine substrates, probably due to a lack of flow or anchor points on the substrate. Shredders of large detrital particles, although not common, reach greater densities on finer substrates than on other substrates, probably due to collection of detrital particles settling out in these slower waters. Periphyton biomass is minimal in these areas. In summary, fine grained substrates in the White River support a biological community of low species richness, density, and biomass.

Intermediate substrate classes support the greatest macroinvertebrate species richness and density of all habitats. Biomass, although not at a maximum, is also high. All functional groups are represented in this habitat type and although collectors are still the predominant group, a larger proportion of these are filterers compared to the silt or sand habitats. Shredders are least important on these substrates. It is interesting to note that free-swimming species, principally Baetis and Isonychia reach their greatest densities on intermediate substrates. This habitat is characterized by a diverse, productive, and highly mobile fauna adapted to exploit a wide variety of energy sources from drifting detritus to periphyton.

The largest substrate sizes are associated with a reduced species richness but slightly higher densities. The biomass increases to a maximum in cobble substrate and decreases slightly in boulder. The most striking change in the fauna located in this habitat type are the increases in filter-feeding insects. Most of the species located in this substate type show adaptations for clinging to the substrate in strong currents. The importance of substrate size in collecting and trapping detritus, and the concurrent effect upon macroinvertebrate densities and biomass has been discussed by Minchell (1969).

The distribution of fish in the White River near the federal lease tracts has also been shown to be related to substrate size (Figure 4.5-33). Although the fish densities are different, speckled dace and roundtail chubs have identical distributions (lowest in sand and silt and highest in cobble and boulder). Bluehead suckers appears to prefer intermediate substrate sizes, while the flannelmouth did not have a substrate preference. These distributions appeared to be related to feeding habits.

4.5.5. Special Study - Yampa River

In July 1981 Colorado River Fisheries Project (CRFP) team of the U.S. Fish and Wildlife Service captured 13 adult Colorado squawfish (Ptychochelius lucius) in one localized area of the Yampa River. These fish, in breeding condition, were concentrated 16.5 miles from the Yampa and Green River confluence (Figure 4.5-34). This large concentration of possibly spawning squawfish provided an opportunity to intensively sample the immediate area in an effort to detect conditions that may have made

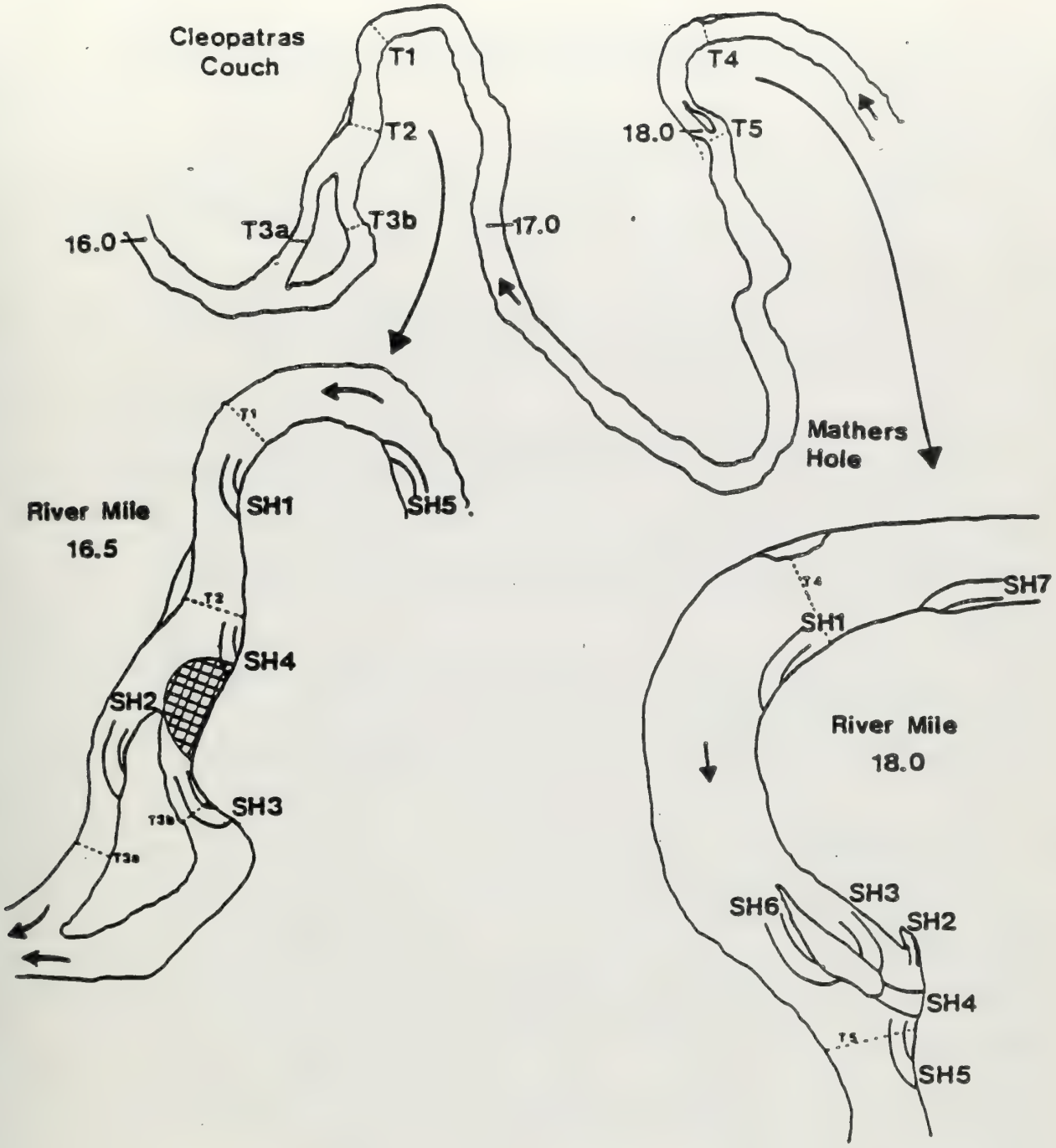

Figure 4.5-34 The locations of the study sites at miles 16.5 and 18.0. SH represents seine haul locations.

the area preferable squawfish habitat. This survey was undertaken on July 24-26, 1981.

The objectives of this study were to:

1. Characterize the river ecosystem at the suspected squawfish spawning site,
2. Establish the interactions of the abiotic environment with the biotic community, and
3. Establish the interactions among and between trophic levels.

The above objectives were accomplished by intensively surveying the area where spawning squawfish were observed (mile 16.5) and comparing these data to another similar site (mile 18.0) which was not used for spawning.

A summary of all parameters measured both in the field and the laboratory can be seen in Table 4.5-7.

4.5.5.1. Results

A. Transect Site Descriptions The general vicinity where CRFP located squawfish is known as Cleopatra's Couch. The site is located 16.5 miles from the confluence of the Green and Yampa Rivers. This study investigated additional areas upstream at river mile 18.0 to provide comparative data. The squawfish were apparently moving in and out of these adjacent areas but not utilizing them for spawning.

In the river system between miles 16.5 and 18.0, steep canyon walls always bordered one shore of the river. Cobble covered islands and shorelines appeared to have been recently exposed by reduced water flows. Beaches within zones of deposition were composed of fine sand or organic

Table 4.5-7 The physical and biological characteristics used to survey the Yampa River ecosystem on July 24-27, 1981 at river mile 16.5 and 18.0.

Transects Locations (T_1, T_2, T_{3A}, T_{3B}, T_4, T_5)

Physical Characteristics:

(1) Distance (meters)
(2) Velocity (2 meter distances, 0.6 distance from the bottom)
(3) Dominant substrate size
(4) Interstitial substrate size factions
(5) Percent organics on the smallest interstitial size class
(6) Detritus levels expressed as total organics dry weight/m^2

Biological Characteristics:

(1) Macroinvertebrate biomass and numbers/m^2 at five or six locations per transect

  (a) Total organisms or biomass
  (b) By order
  (c) By functional group

(2) Periphyton biomass determined by chlorophyll a/m^2 at five or six locations per transect

Seine Haul Locations

Physical Characteristics:

(1) Depth (taken at four locations equidistant through the seine haul area)
(2) Velocity (taken at four locations equidistant through the seine haul locations)
(3) Dominant substrate size
(4) Detritus levels expressed as total organics dry weight/m^2

Biological Characteristics:

(1) Macroinvertebrates biomass and numbers (m^2 at each seine haul location)

  (a) Total organisms
  (b) By order
  (c) By funtional group

(2) Drift - samples collected six times over 24 hours at river mile 16.5 and two times over six hours at river mile 18.0

  (a) Total organic detrital drift (grams/hour)
  (b) Macroinvertebrates (numbers/hour) total numbers and totals by order
  (c) Velocity at the location

(3) Fish - seine hauls taken five times over 24 hours at river mile 16.5 and two times over six hours at river mile 18.0 Seine hauls correspond to macroinvertebrate and drift locations

  (a) Total numbers of all fish/seine haul
    - length
    - species
  (b) Stomach samples
    - total analysis of all fractions and organisms
    - total settleable volumes (0.01 mis)
    - size distribution of all items in stomachs
    - total biomass/stomach, calculated
    - total settleable volumes/stomach (0.01 mis)

silt-mud deposits. Backwater areas of the river were often marshy with loose organic substrates.

At river mile 16.5 and 18.0, transects were established in areas which reflected the maximum number of habitat types found in the river. These data can be seen in Figures 4.5-35 and 4.5-36. Although a comparison of the water depth, water velocity, and substrate size for these transects indicated that Transects 1, 3, and 5 represented runs or riffles of various sizes and Transects 2 and 4 were indicative of deep runs or pools, it was difficult to rigidly classify the habitats. For example, the riffle transects tended to have higher average velocities and were shallower in depth, whereas the run-pool transects were deeper and had lower velocities. But a comparison of the biological data indicate the highest (Transect 2, 31.6 $\pm$ 6.7 mg/m^2) and lowest (Transect 4, 7.8 $\pm$ 5.9 mg/m^2) periphyton biomasses were found in pools. However, substrate sizes, both dominant and interstitial fractions and benthic detritus were different in these two transects (Table 4.5-8) with smaller sizes and higher detritus found in Transect 2.

Maximum average biomass of macroinvertebrates were found in Transect 3 (10.8 $\pm$ 4.07 gms/m2) and Transect 5 (13.79 $\pm$ 3.27 gms/m2) and corresponded to highest water velocites.

A comparison between Transect 2 and Transect 3a-3b indicated marked differences in these two habitat types. The major abiotic differences between these two transects were the dominant and interstitial substrate sizes. Transect 2 had sand and silt as the dominant substrate with interstitial substrates less than 0.5 mm in size. However, at Transect 3a-3b, the dominant substrate was cobble with all interstitial substrates

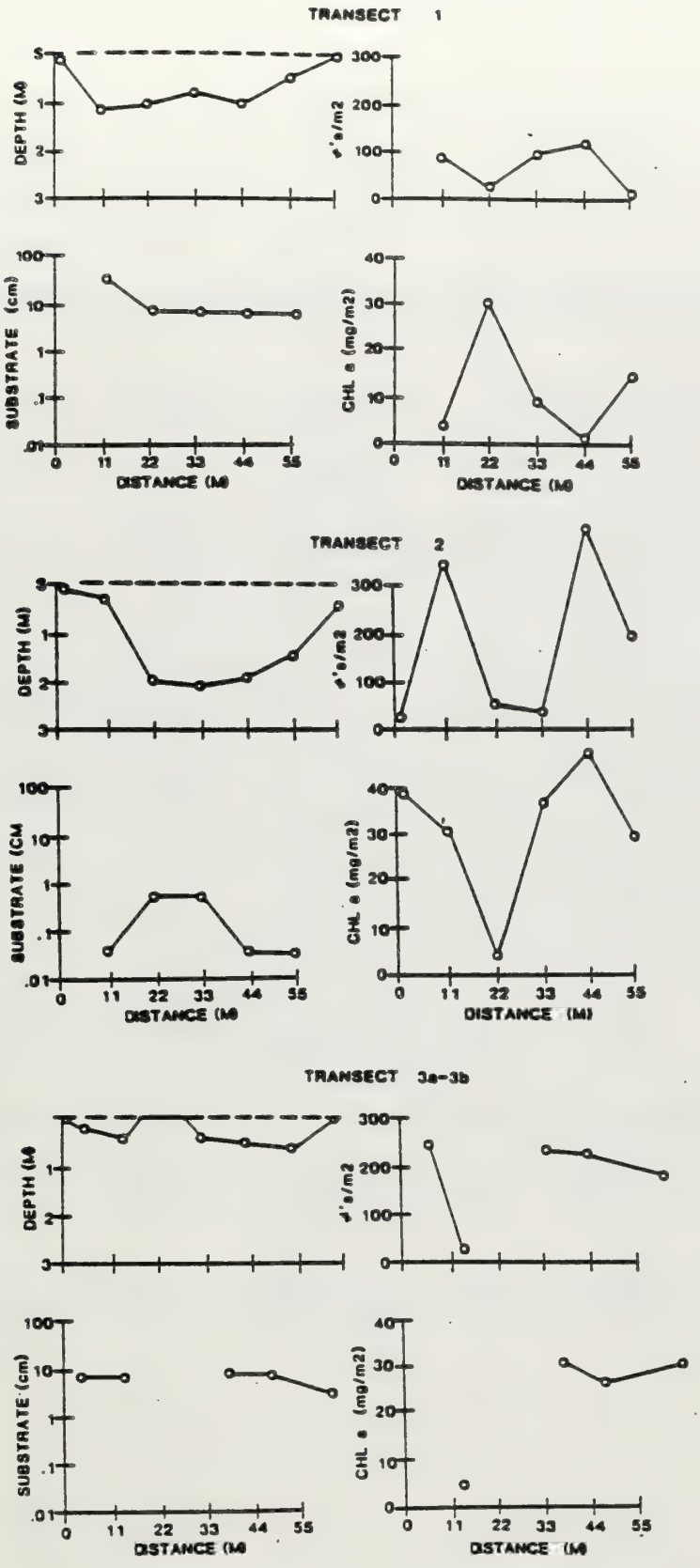

Figure 4.5-35 The physical and biological data collected at Transects 1, 2 and 3a-3b near river mile 16.5 on the Yampa River. Data collected July 24-26, 1981. These data included water depth (m), dominant substrate size (cm), periphyton biomass (mg Chl a/m^2), and macroinvertebrate density (#'s/m^2).

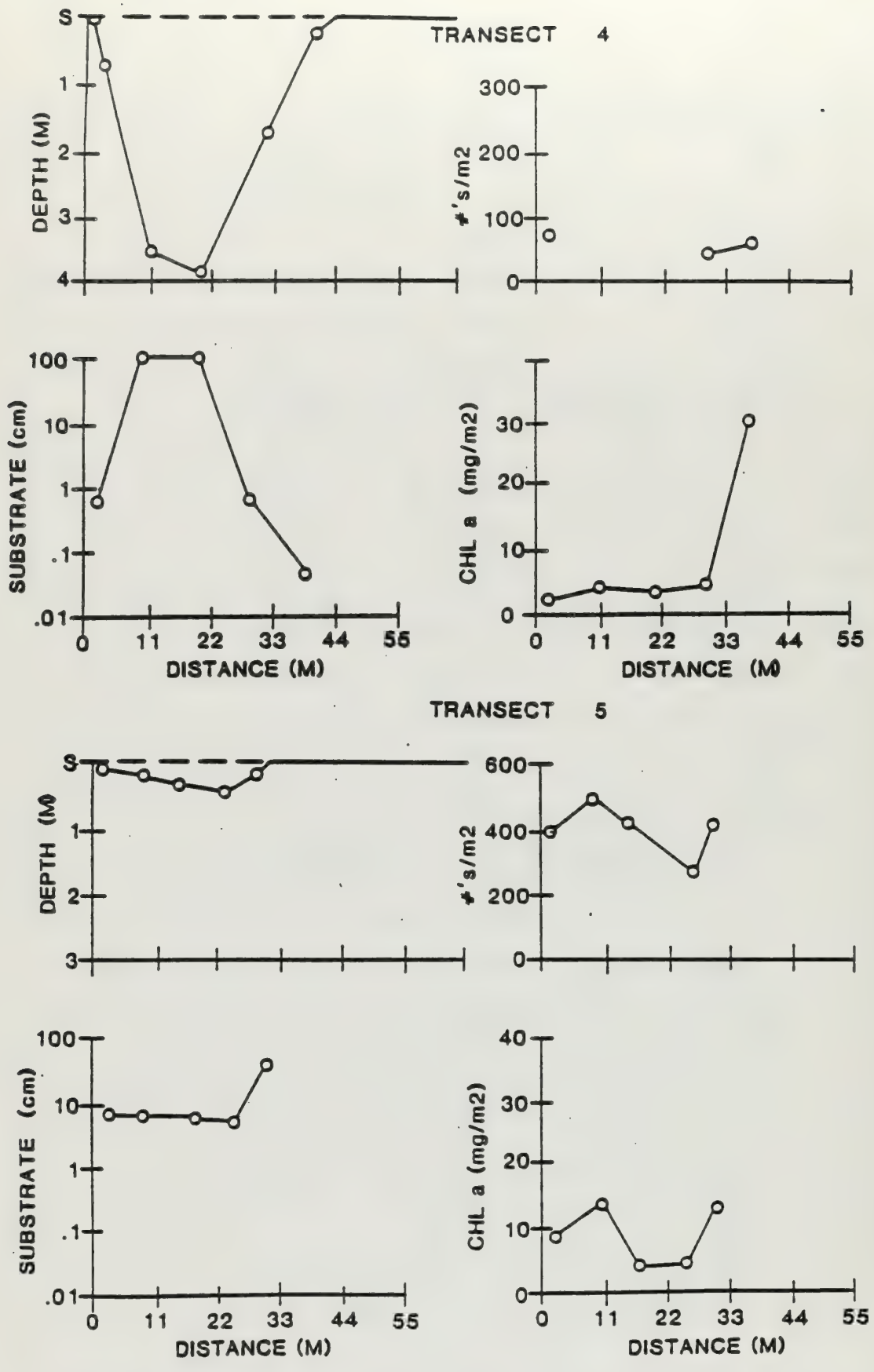

Figure 4.5-36 The physical and biological data collected at Transects 4 and 5 near river mile 18.0 on the Yampa River. Data collected July 24-26, 1981.

Table 4.5-8 Physical and biological data summary for each transect sample location.

Location		Chl a (mg/m^2)	Depth (m)	Velocity (m/sec)	Dominant Substrate (cm)	Sediment Size Fractions %*						Total Detritus (gms/m^2)	Macroinvertebrates	
						A	B	C	D	E	% Organics		Total ($\#/m^2$)	Total Biomass (gms/m^2)
T_1	11	4.4	1.1	0.55	15.0	0	0	3	33	64	0.83	39.35	80	0.96
	22	31.3	1.0	0.70	7.5	73	2	7	11	7	0.07	0.25	30	0.09
	33	9.9	0.8	0.75	7.5	65	10	10	11	4	0.03	2.33	102	2.41
	44	0.7	1.0	0.80	7.5	67	18	10	4	1	0.01	1.71	124	1.26
	55	14.7	0.5	0.35	7.5	8	0	1	65	25	0.20	1.96	10	0.01
T_2	1	39.1	0.37	0.03	0.05	0	36	14	5	46	0.85	3.21	10	0.02
	11	31.3	2.10	0.17	0.05	0	0	66	29	5	0.17	23.60	351	1.33
	22	4.2	2.20	0.60	0.75	0	0	1	79	20	0.11	0.20	40	0.11
	33	37.1	2.03	0.48	0.75	0	0	0	40	60	0.42	2.23	20	0.05
	44	48.9	1.55	0.30	0.05	0	0	11	31	59	1.10	54.11	501	3.44
	54	29.2	0.35	0.20	0.05	0	0	0	18	82	0.98	10.34	197	1.13
T_{3A}	6	--	0.21	1.70	7.5	59	23	15	3	0	0.01	2.53	1384	26.41
	13	4.6	0.39	3.10	7.5	75	17	6	2	0	0.00	0.27	140	3.17
T_{3B}	4	31.3	0.30	1.40	7.5	67	17	9	6	2	0.02	6.48	250	8.67
	13	27.4	0.36	2.05	7.5	82	13	3	2	0	0.01	1.18	245	9.91
	30	31.3	0.52	2.90	2.5	61	24	11	4	1	0.01	0.46	205	5.85
T_4	2	1.5	0.75	0.0	0.75	0	0	1	24	75	0.66	5.30	70	4.71
	11	1.9	3.75	0.90	15.0	99	0	0	0	1	0.00	--		
	20	1.7	4.20	1.35	15.0	37	1	14	46	2	0.02	--		
	29	2.4	2.38	0.55	0.75	0	0	20	67	13	0.10	0.13	20	0.07
	38	31.3	0.30	0.15	0.05	0	0	16	56	28	0.47	31.27	70	0.46
T_5	3	8.8	0.14	1.15	7.5	96	4	0	0	0	0.00	1.59	432	23.76
	10	13.9	0.27	4.10	7.5	63	27	8	1	1	0.01	2.01	502	19.30
	17	4.2	0.43	4.60	7.5	63	27	11	0	1	0.00	0.33	442	8.69
	24	4.2	0.52	5.00	7.5	67	20	11	2	1	0.01	0.26	248	6.98
	31	12.7	0.26	2.70	15.0	82	9	5	3	1	0.01	12.08	406	10.25

*Sediment Size Fractions:

A = >14.7
B = 14.7 - 4.0
C = 4.0 - 0.5
D = 0.5 - 0.25
E = <0.25

being greater than 4 mm. On this transect, the cobble provided substantial interstitial voids.

It should be noted that the CRFP (1982) observed squawfish moving from the area of Transect 2 into and out of the cobble area of Transect 3b in apparent spawning behavior (Figure 4.5-34). Both dominant and interstitial substrate characteristics at Transect 3a-3b may be critical in the apparent preference of this habitat by spawning Colorado squawfish. At river mile 18.0, a physically similar habitat was found (Transect 5 in Table 4.5-8). However, this transect had extremely high velocities (4.5 m/sec) which may have precluded this area from being used for spawning activities.

B. Seining Locations Five selected sites around river mile 16.5 were sampled intensively for fish, larval fish, macroinvertebrate drift, and benthic macroinvertebrates. Each of the five seine haul sites were sampled five times at four-hour intervals. At river mile 18.0, seven sites were sampled twice over an eight-hour period. A comparison of the physical and biological date collected at the seining sites (see Figure 4.5-34), indicates that these parameters fall within the ranges observed on the transects (Table 4.5-9).

The total number of fish captured by seining can be seen in Table 4.5-10. Ten species of fish were captured during this intensive survey. Six species were endemic and four species were exotic. Among the endemics, the largest number captured were roundtail chubs (39% of the total) followed by specked dace (20%). One humpback chub was captured. Redside shiners were the most abundant exotic (15%) followed by red shiners (13%). The ratio of endemic to exotics was approximately 2:1 by density.

Table 4.5-9 The physical and biological data collected at the seining sites from RMS 16.5 on the Yampa River, July 24-26, 1981.

Location RM	SN	Time (hours)	Area Sampled (m^2)	Depth (meters)	Velocity (m/sec)	Dominant Substrate (cms)	Substrate Organics (gms/m^2)	Macroinvertebrates Density ($\#'s/m^2$)	Macroinvertebrates Biomass (gms/m^2)
16.5	SN_1	1620 2030 0000 0910 1435	60	0.44	0.02	2.5	0.26	50	1.252
16.5	SN_2	1640 2100 0020 0935 1510	36	0.88	0.23	7.5	1.05	312	18.43
16.5	SN_3	1700 2100 0040 0955 1535	30	0.38	1.07	0.75	0.06	777	24.599
16.5	SN_4	1715 2125 0100 1010 1605	45	0.78	0.14	0.75	1.55	91	5.952
16.5	SN_5	1745 2140 0125 1030 1630	45	0.67	0.30	7.5	0.25	11	0.01

Table 4.5-10 The fishes captured on the Yampa River by seining at river mile 16.5 and 18.0, July 24-26, 1981.

Fish Species (Seining)	Species Code	Young of the Year w/Food	Young of the Year w/o Food	Subadults/Adults w/Food	Subadults/Adults w/o Food	Total Fish Captured YOY	Total Fish Captured SA/A	Total Fish Captured Grand Total	% of Total	CRFP (1982)
Bluehead sucker *Catostomus discobolus*	BH	1	0	8	0	1	8	9	3%	4%
Flannelmouth sucker *Catostomus latippinis*	FM	5	1	6	0	6	6	12	4%	5%
Fathead minnow *Pimephalus promelas*	FH	0	0	1	0	0	1	1	<1%	6%
Red Shiner *Notropis lutrensis*	RS	0	0	36	2	0	38	38	13%	16%
Redside shiner *Richardsonius baltcatus*	RD	0	0	40	4	0	44	44	15%	8%
Roundtail chub *Gila robusta*	RT	36	4	69	5	40	74	114	39%	32%
Sand shiner *Notropis stramineus*	SS	0	0	10	2	0	12	12	4%	3%
Speckled dace *Rhinichthys oculus*	SD	2	0	50	8	2	58	60	20%	21%
Channel catfish *Ictalurus punctatus*	CC	1	0	0	0	1	0	1	<1%	2%
Humpback chub *Gila cypha*	HB					0	1	1	<1%	0%

The distribution of these fish between seining sites and over time was not constant. The diurnal movements observed at mile 16.5 were primarily roundtail chubs.

The temporal distribution of fish captured at the lower end of the cobbled-riffle area (SH2 and SH3) was the lowest observed at any site (Figure 4.5-37). It was apparent that fish were not moving into or out of this fast riffle area. A comparison of all seining sites between 1620 and 1745 hours indicated that maximum density of fish was found at SH4 (.44 fish/m^2 sampled). Subsequent seine hauls taken at this site, showed continuously reduced densities over the 24 hours sampled. A comparison of the other sites indicated the opposite pattern at the upper site (SH5) with no change in the intermediate seining location (SH1). It was belived that fish were moving out of the deep pool (SH4) past SH1, and towards SH5 which was located at the lower stretch of a riffle area.

Drift samples were taken at each seining location, and analyzed for macroinvertebrates (#'s/hour) and, larvel fish (#'s/hour). These data can be seen in Figure 4.5-38. A comparison of the drift entering (SH4) and leaving (SH2-SH3) (the riffle area where squawfish were at their highest observed concentrations), indicated that substantial numbers of macroinvertebrates and larval fish originated within this habitat. For example, the duirnal pattern of drift (macroinvertebrates and larval fish) reached a maximum between 2125 and 0100 hours. No larval fish and only 500 macroinvertebrates/hr were captured entering the area, whereas over the same time period five larval fish/hr and over 2000 macroinvertebrates/hr were estimated to be leaving this riffle area. Although drift nets were located at each seining location, larval fish were only

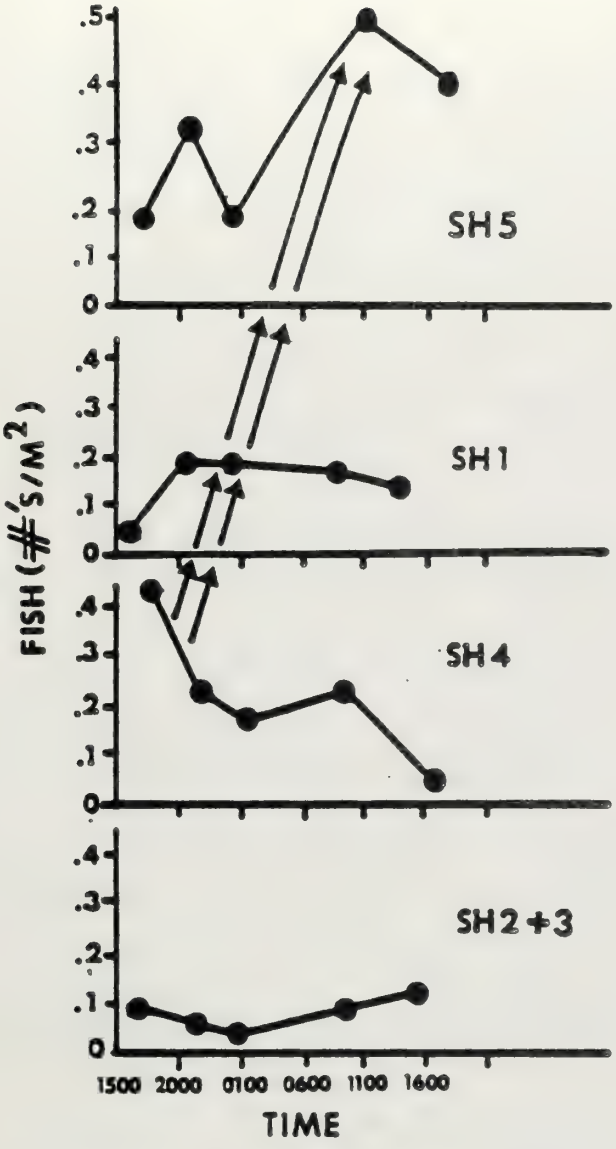

Figure 4.5-37 The distribution of fish captured at each seining site over a 24-hour period, July 24-26, 1981.

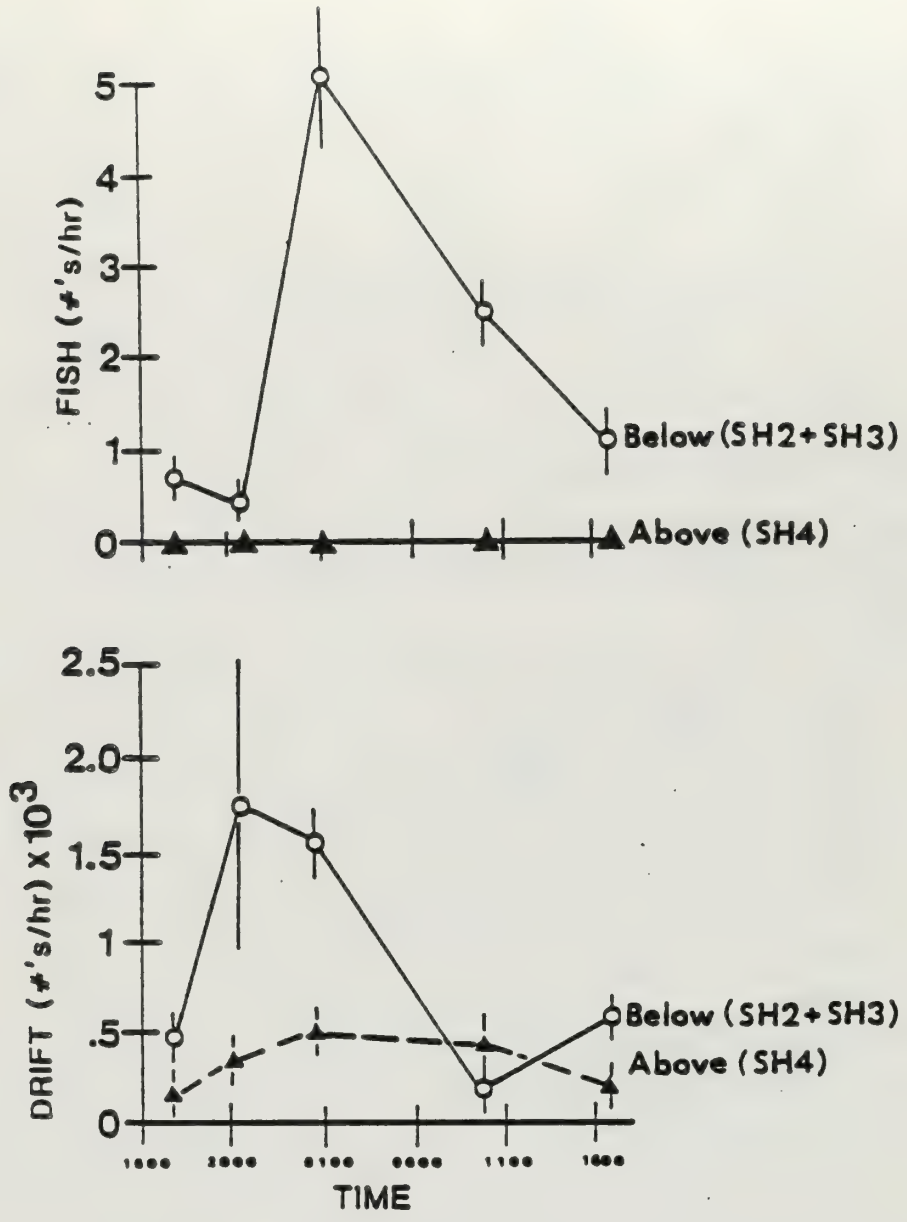

Figure 4.5-38 The density of drift macroinvertebrates (#'s/hour) and larval fish (#'s/hour) captured at selected seining sites (SH) at river mile 16.5 on the Yampa River. Data collected between July 24-26, 1981.

collected in nets below this cobble area. Five species of larval fish were identified (SD=speckled dace, RT=roundtail chub, CC=channel catfish, FM=flannelmouth sucker, and CP=carp), indicating that this habitat may have been used for spawning or as a nursery area by species other than squawfish. Several species still contained yolk sacks.

Feeding habitats were determined by comparing benthic and drift samples to fish stomachs for the locations and times fish were captured (Strauss 1979; 1981). Feeding intensity was determined by using a percent of stomach volume filled. In Table 4.5-11, a comparison is given between the major macroinvertebrate components in the drift or benthos to the major components of each species diet (dominant four fish species only). This data indicates (and is reflected in Strauss Electivity Index, Table 4.5-12) that the two endemics: roundtail and speckled dace have a much richer diet relative to available food when compared to redside and red shiners. The latter two introduced species may be opportunistic and appear to eat food items in the proportion that they are available.

Feeding intensity between species (as determined by percent fullness) indicated that red shiners had significantly fuller stomachs (62.6 $\pm$ 4.5 percent) when compared to all species except sand shiners (49.4 $\pm$ 8.9 percent). All other species were not significantly different (Table 4.5-13). Comparing all fish species combined over time (Figure 4.5-39), indicated that fish captured between 1950-2140 hours had significantly higher percent fullness (56.2 $\pm$ 3.6%) compared to the other four time periods (41.7 $\pm$ 2.4). This time period corresponded to maximum invertebrate drift (Figure 4.5-38).

Table 4.5-11 The percent composition of the diet of fish (A) and the benthic or drift macroinvertebrates (B) samples collected in the Yampa River near river mile 16.5 between July 24-26, 1981.

(A) Percent in Each Fish Species Diet

Insect Orders	Redside Shiner	Red Shiner	Roundtail Chub	Speckled Dace	All Species
Ephemeroptera	.927	.926	.786	.875	.858
Plecoptera	-	-	.001	-	.000
Trichoptera	.001	-	.051	.042	.031
Coleoptera	-	-	-	.023	.006
Diptera	.056	.015	.132	.058	.078
Hymenoptera	.013	.043	.029	-	.022
Lepidoptera	-	-	-	.002	.001
Hemiptera	.004	.016	.001	.001	.004
Hydracrina	-	-	.001	-	.000

(B) Percent in Each Sample Type

Insect Orders	Benthic	Drift
Ephemeroptera	.9426	.9958
Plecoptera	.0087	.0009
Trichoptera	.0425	.0022
Coleoptera	.0004	.0001
Diptera	.0012	.0008
Odonata	-	.0001
Lepidoptera	.0008	-
Hemiptera	.0009	.00001
Homoptera	.0002	.000002
Arachnida	-	.00001
Megaloptera	-	.0001
Annelida	.0019	-

Table 4.5-12 The calculated linear Electivity Index (Strauss 1979) for the dominant four fish species in the Yampa River near river mile 16.5. Electivity comparisons are made for the benthos (A) and drift (B) organisms. Data collected between July 24-26, 1981.

(A) For Benthos

Insect Orders	Redside Shiner	Red Shiner	Roundtail Chub	Speckled Dace	All Species
Ephemeroptera	-.016	-.017	-.157	-.068	-.085
Plecoptera	-.009	-.009	-.008	-.009	-.009
Trichoptera	-.042	-.043	.008	-.001	-.012
Coleoptera	.000	.000	.000	.023	.006
Diptera	.055	.014	.131	.057	.077
Hymenoptera	.013	.043	.029	.000	.022
Lepidoptera	-.001	-.001	-.001	.000	.000
Hemiptera	.003	.015	.000	.000	.003
Homoptera	.000	.000	.000	.000	.000
Annelida	-.002	-.002	-.002	-.002	-.002
Hydracrina	.000	.000	.001	.000	.000

(B) For Drift

Insect Orders	Redside Shiner	Red Shiner	Roundtail Chub	Speckled Dace	All Species
Ephemeroptera	-.069	-.070	-.210	-.121	-.138
Plecoptera	-.001	-.001	.000	-.001	-.001
Trichoptera	-.001	-.002	.049	.040	.029
Coleoptera	.000	.000	.000	.023	.006
Diptera	.055	.014	.131	.057	.077
Odonata	.000	.000	.000	.000	.000
Hymenoptera	.013	.043	.029	.000	.022
Lepidoptera	.000	.000	.000	.002	.001
Hemiptera	.003	.015	.000	.000	.003
Homoptera	.000	.000	.000	.000	.000
Arachnida	.000	.000	.000	.000	.000
Megaloptera	.000	.000	.000	.000	.000
Hydracrina	.000	.000	.001	.000	.000

Table 4.5-13 The analysis of variance for percent fullness of stomachs for (A) treatment, by species, and (B) treatment, all species combined, by time. Using Fishers LSD, in (A) red shiners were significantly fuller than all other species and (B) fish captured between 1950-2150 hours were significantly fuller than the other four time periods.

Treatment	DF	SS	MS	F-Ratio	P
(A) Species	6	1.395	.2326	2.99	<.01
Error	276	21.480	.0778		
Total	282	22.876			
(B) Sample Times	4	1.1588	.2897	3.65	<.01
Error	280	22.232	.0794		
Total	284	23.391			

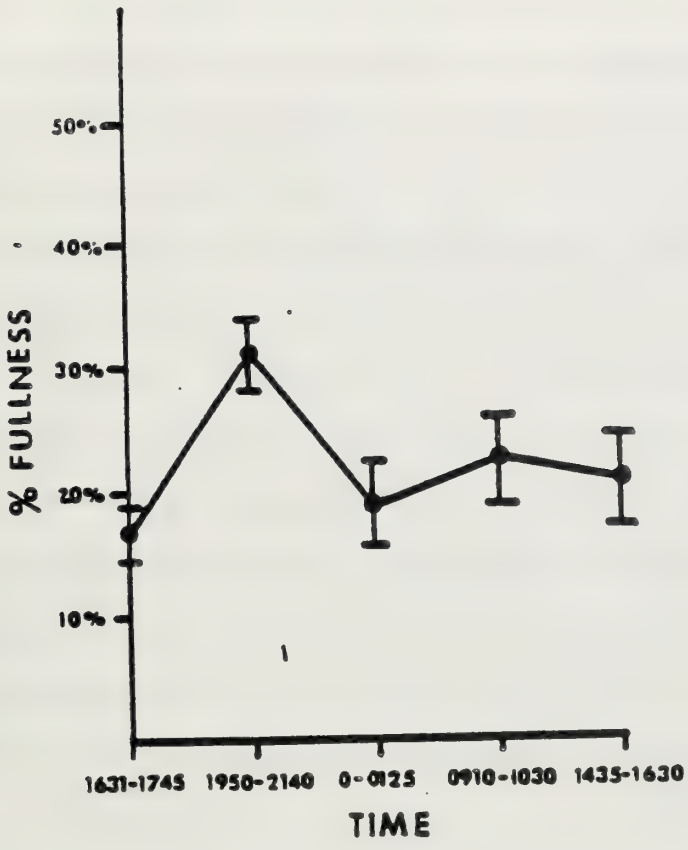

Figure 4.5-39 The feeding intensity (expressed as a percent of fullness of stomach volume) of all fish compared over time at Yampa River mile 16.5. Fish captured between 1950-2140 hours were significantly fuller than fish captured at other times. Data collected between July 24-26, 1981.

4.5.5.2. Discussion One of the major objectives of this study was to determine the unique physical and biological features which had made Yampa River Mile 16.5 attractive to spawning Colorado River squawfish. Ideally, these data presented here should have been collected during early July when spawning fish were observed at the site. During the CRFP (1982) survey, at Transect 2 the width of the river was estimated to be 70 meters compared to a survey distance of 54 meters reported here. Although both sample periods were during postrunoff, the river had dropped approximately 0.6 meters with a reduced flow from 480 cfs to 300 cfs. It is doubtful, therefore, that the physical environment had changed between the two sampling periods.

The biological community quantified in this report was similar to other studies. The dominant macroinvertebrates (Ephemeroptera: Rhitheogena, Baetis; Plecoptera: Isogenus; Trichoptera: Hydropsche), given in order of abundance, were also previously reported by Bailey and Alberti (1952) and more recently by Carlson et al., 1979 and Annear, 1980. The density of macroinvertebrates also correspond to the levels reported by Annear (1980).

The fish species composition of the Yampa River within Dinosaur National Park has changed dramatically within the recent past. Carlson et al. (1979) noted that Holden (1973) reported bonytail chub, largemouth bass, bluegill, sunfish, and walleye within this stretch of river. However, six years later these species were not located but plains killfish and sand shineres were collected (Seethaler at al. 1979). Carlson's et al. (1979) data and the data reported here are most similar. A comparison of the most recent collections (CRFP 1982) to this study can be seen

in Table 4.5-10. The most notable differences were: (1) the absence of squawfish and the presence of a humpback chub in our collections and (2) the higher densities of redside shiners in our collections when compared to CRFP (1982) data.

It has been noted by Crosby (1975), Lanigan and Berry (1979), Prewitt et al. (1978), and Valdez (1982) that the proportion of exotic to endemic fish increased as the major tributary streams approached their confluences with the Green River. Lanigan and Berry (1979) attributed the higher proportion of exotics to a decrease in habitat diversity, whereas Valdez (1982) has suggested that habitats occupied by some native fishes are unfavorable to some exotics.

Although no longitudinal data was collected in this study, a low proportion of exotic to endemics (1:2) was found. A comparison of their distributions will be discussed later, but it should be noted that a wide diversity of habitats was found in this lower river section.

The determination of fish species distribution, food selection, and feeding intensities were accomplished by using a diurnal sampling scheme for fish, drift insects, and larval fish. These data have provided insight into the structure and function of this ecosystem. It is interesting to note that larval fish were captured only in the vicinity where squawfish had been collected and that their movement corresponded to macroinvertebrate drift (2125-0100 hours). Five species of larval fish emerged from this cobble site. Furthermore, the inspection of the data collected at each seining site indicated a potential movement of fish from this same area at approximately the same time (Figure 4.5-37). This would indicate that the habitat was utilized by species other than

Colorado squawfish. One of the important characteristics of this cobble area was the amount of well-washed interstitial voids which contain little or no organics. The difference in drift above and below this area indicates their use of these interstitial voids. Prewitt et al. (1982) has indicated that other similar habitats exist in the White River, a major tributary to the Green River. However, their analysis of physical habitat and streamflow requirements for spawning squawfish consider only substrate size, not interstitial particles or voids. In the White River, the armored sediments prevent interstitial voids from developing, thus making the cobble habitat at Yampa River Mile 16.5 unique in comparison to other previously observed sites in the White River.

The physical factors which regulate the distribution of organisms in stream environments are varied. Such factors as nutrients (Church et al. 1978) turbidity (Buck 1956), temperature (Nebeher 1971), light (Westlake 1966), and water velocity (McIntire 1970) have been shown to have profound effects on the river biocenosis. In this study, certain physical factors were also shown to be important in determining the distribution of the aquatic community. A comparison of the major trophic levels (primary producers, detritus levels, macroinvertebrates, and fish) indicated that the distribution may be related to substrate size (Figures 4.5-40 and 4.5-41). The same general pattern appeared for all of the major groups or oganisms: avoidance of sand (.25 cms) and selection for either small substrate (<.075 cm) or larger substrate (2.5 to 10 cms). Examination of the interactions between these biotic components and substrate size appears to be consistent with the findings of Cummins and Lauff (1969) and Rabeni and Minshall (1977).

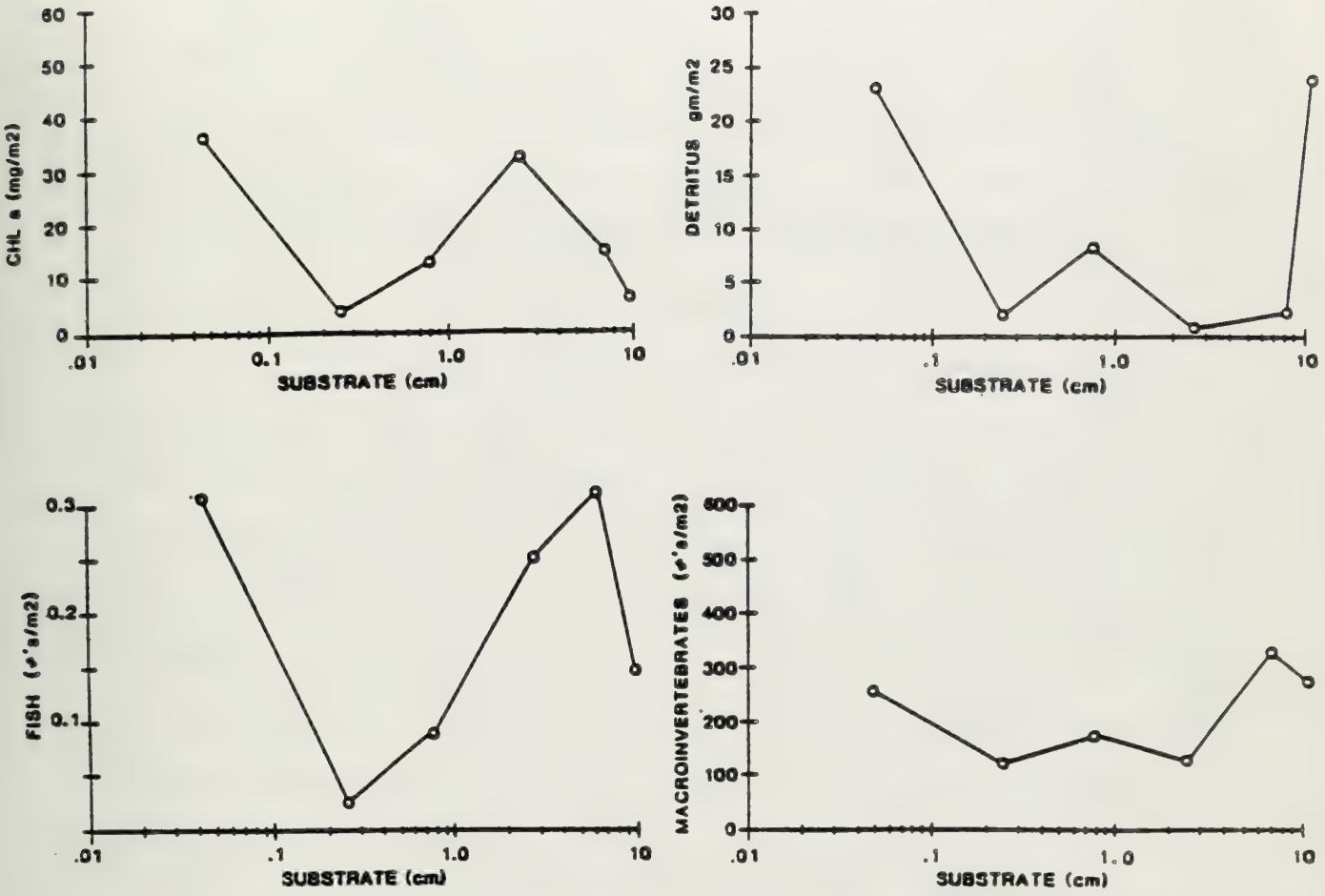

Figure 4.5-40 The distribution of periphyton (mg Chl a/m^2), total fish density (#'s/m^2), detritus (gm/m^2), and macroinvertebrate densities (#'s/m^2) by substrate size in the Yampa River. Data collected between river mile 16.5 and 18.0 on July 24-26, 1981.

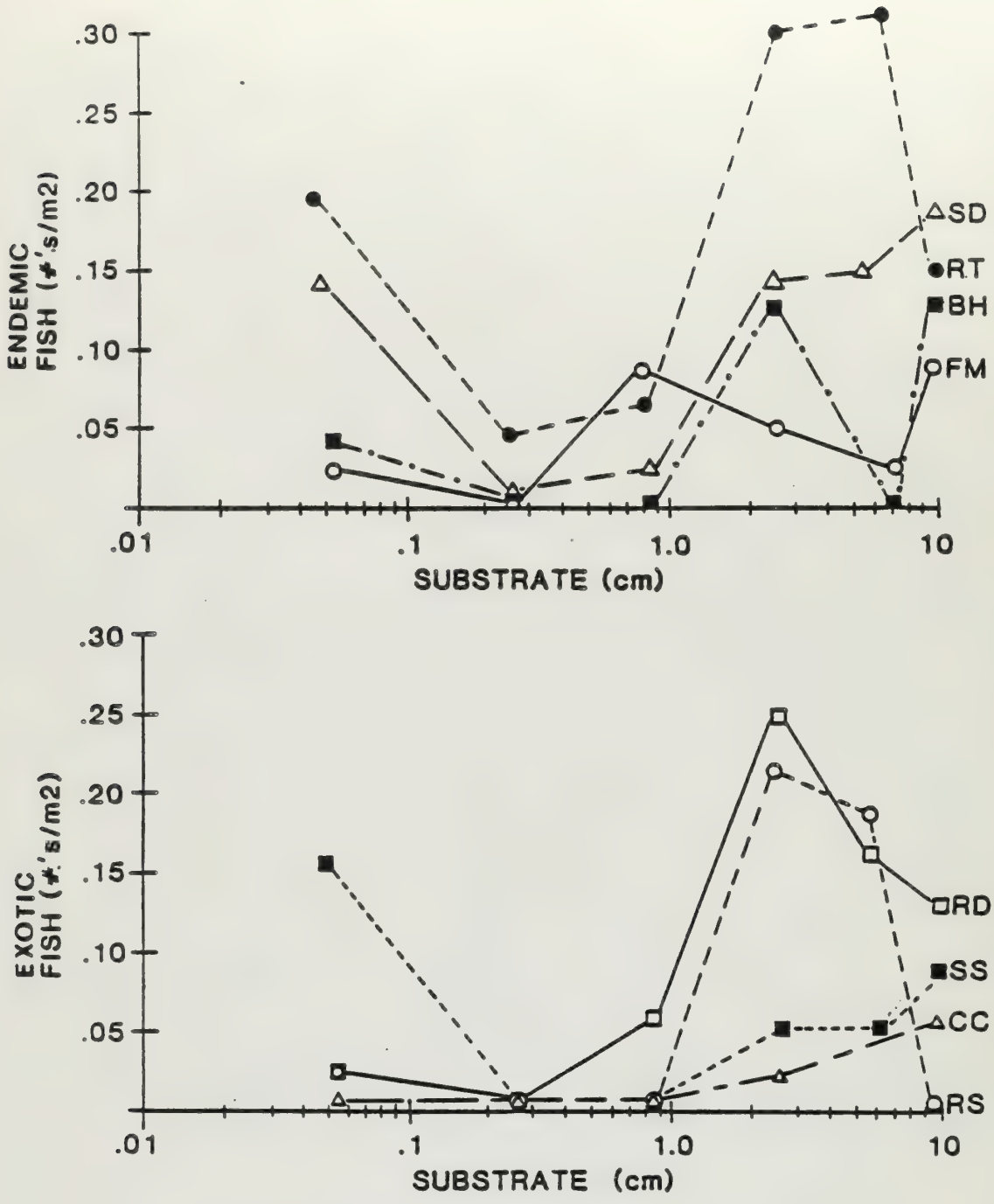

Figure 4.5-41 The distribution of fish by species over substrate types in the Yampa River. Fish were collected between river mile 16.5 and 18.0 on July 24-26, 1981.

The distribution of fish across the various substrate sizes was different depending upon the species. The endemic fish appeared to avoid sand and gravel and select intermediate to large substrates. Within the exotic species, sand shiners appeared to prefer environmental conditions associated with the smallest substrate; whereas, the red shiner and red-side shiner favored intermediate (2.5 to 7.5 cms) substrates. All species avoided sand. The mechanisms causing the above observed distributions of endemic and exotic fish are unknown; however, the similar distributions of the fish, periphyton, and macroinvertebrates may be interrelated.

As noted previously, the density of the river biocenosis changed markedly over different substrate types; however, as Carlson et al. (1979) has stated, the distribution of organisms may be more influenced by combinations of the effect of physical and biotic characteristics than by physical factors alone. Our data indicates these types of interrelationships are important in the Yampa River. For example, no statistical relationship was found between the biomass of macroinvertebrates and the biomass of periphyton or detritus; however, a significant relationship was found between water velocity and macroinvertebrate biomass (r^2 = +.45; p = .01). This relationship was believed to be indirect because the dominant benthic macroinvertebrate functional group was found to be fine particulate collectors or filter feeders (98 percent of the total biomass) which may be responding to areas of food availability.

The Yampa River at mile 16.5, a documented spawning site for Colorado squawfish, was dominated by loose cobble substrate in association with large sandy pools. These spawning areas were also found to be free

of small interstitial substrates (Table 4.5-8) and organic material (Figure 4.5-40). This area appeared to be heavily used by larval fish and actively feeding adults. The combination of well-washed large substrate (cobble), abundant food (both drift and benthos), and adjacent areas with slow, uniform laminar flow may be critical factors in determine prefered squawfish reproductive sites. It was also apparent that other species have similar preferences.

4.5.5.3. Conclusions The following conclusions can be drawn from this study:

1. A dominant abiotic factor appeared to be substrate type
    a) Yampa River Mile 16.5 was dominated by cobble substrate.
    b) Associated with these cobble areas were sandy pools.
    c) Periphyton, macroinvertebrates, and fish were found in lowest densities in or on sandy substrates.
    d) Highest densities of periphyton macroinvertebrates, and fish were found over substrates smaller than boulders (except sand).
    e) Roundtail chubs dominated the endemic fishes and preferred cobble substrate.
    f) Exotics were dominated by redside shiners and red shiners, and both species were most abundant over cobble substrates.
    g) Sand shiners were the only species to demonstrate a preference for silt substrates.

2. Samples collected diurnally showed nocturnal hours to be important periods of biological activity.

a) Periods of highest macroinvertebrate drift occurred between 1500 and 0200 hours.

b) Drifting larval fish were collected only after 2000 hours with the peak occurring at 0-0125 hours.

c) Drifting larval fish appear to be leaving a cobble substrate with substantial interstitial voids.

d) Maximum feeding intensity of fish captured occurred between 1950-2140 hours.

e) Fish were found to move from the sandy-pool area into the lower sections of riffles during the same period of time when maximum feeding intensity was observed.

4.5.6 Literature Cited

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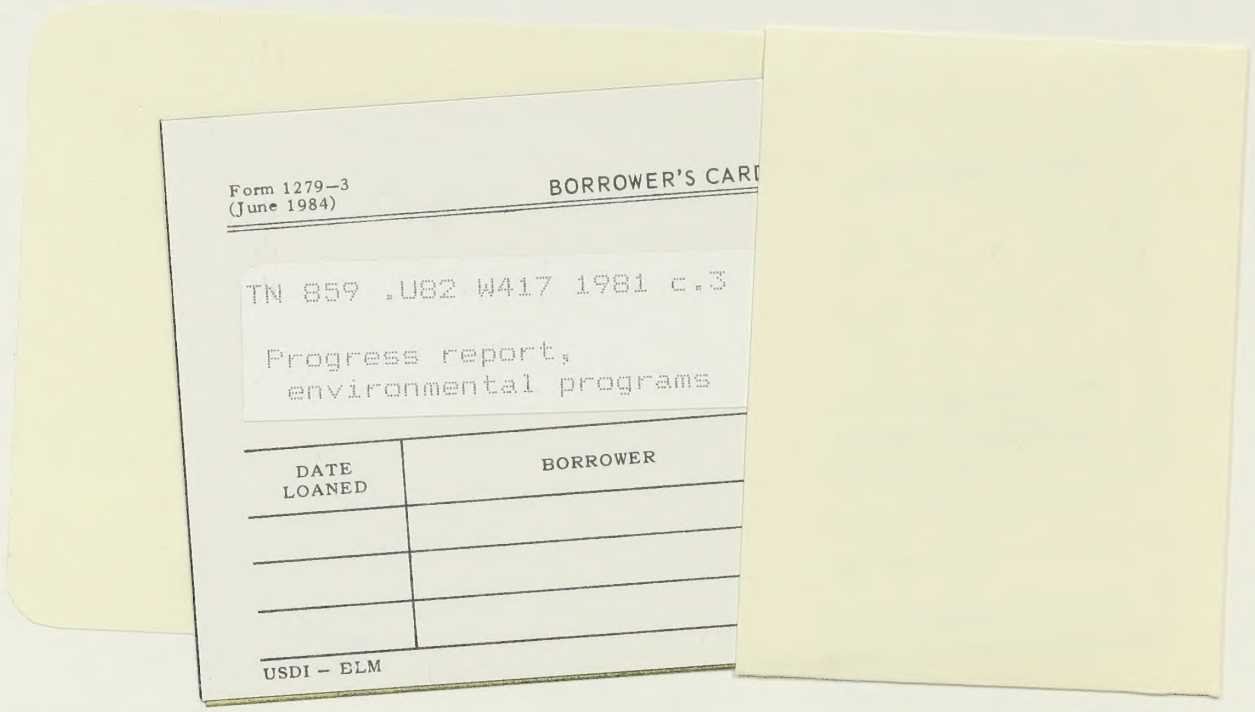
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